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(21) International Application Number: PCT/CA96/00049 (22) International Filing Date: 24 January 1996 (24.01.96) (30) Priority Data: 08/387,156 10 February 1995 (10.02.95) US (71) Applicant: UNIVERSITY OF SASKATCHEWAN [CA/CA]; 210 Kirk Hall, Saskatoon, Saskatchewan S7N 0W0 (CA). (72) Inventors: POTTER, Andrew, A.; 521 Dalhousie Crescent, Saskatoon, Saskatchewan S7H 3S5 (CA). MANNS, John, G.; 11 Pony Trail Road, Riverside Estate, Saskatoon, Saskatchewan S7T 1A1 (CA). (74) Agents: ERRATT, Judy, A. et al.; Gowling, Strathy & Henderson, Suite 2600, 160 Elgin Street, Ottawa, Ontario K1P 1C3 (CA).		(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AZ, BY, KG, KZ, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
(54) Title: GnRH-LEUKOTOXIN CHIMERAS (57) Abstract New immunological carrier systems, DNA encoding the same, and the use of these systems, are disclosed. The carrier systems include chimeric proteins which comprise a leukotoxin polypeptide fused to a selected GnRH multimer which consists essentially of at least one repeating GnRH decapeptide sequence, or at least one repeating unit of a sequence corresponding to at least one epitope of a selected GnRH molecule. Under the invention, the selected GnRH sequences may all be the same, or may correspond to different derivatives, analogues, variants or epitopes of GnRH so long as the GnRH sequences are capable of eliciting an immune response. The leukotoxin functions to increase the immunogenicity of the GnRH multimer fused thereto.		

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GnRH-LEUKOTOXIN CHIMERASDescriptionTechnical Field

10 The present invention relates generally to immunological carrier systems. More particularly, the invention pertains to leukotoxin-GnRH chimeras including more than one copy of a GnRH polypeptide, which demonstrate enhanced immunogenicity as compared to the
15 immunogenicity of GnRH polypeptides alone.

Background of the Invention

 In vertebrates, synthesis and release of the two gonadotrophic hormones, luteinizing hormone (LH) and
20 follicle stimulating hormone (FSH), are regulated by a polypeptide referred to as Gonadotropin releasing hormone (GnRH) (formerly designated LHRH). Accordingly, one approach to fertility control in an animal population is to reduce the levels of GnRH, such as by immunization
25 against GnRH, which effects a reduction in the levels of LH and FSH and the concomitant disruption of estrous cycles and spermatogenesis. See e.g., Adams et al., *J. Anim. Sci.* (1990) 68:2793-2802.

 In particular, early studies of the GnRH
30 molecule have shown that it is possible to raise antisera in response to repeated injections of synthetic GnRH peptides (Arimura et al., *Endocrinology* (1973) 93(5):1092-1103). Further, antibodies to GnRH have been raised in a number of species by chemical conjugation of
35 GnRH to a suitable carrier and administration of the

conjugate in an appropriate adjuvant (Carelli et al.,
Proc. Natl. Acad. Sci. (1982) 79:5392-5395). Recombinant
fusion proteins comprising GnRH or GnRH-analogues have
also been described for use in peptide vaccines for the
5 immunological castration or inhibition of reproductive
function of various domesticated and farm animals (Meloan
et al., *Vaccine* (1994) 12(8):741-746; Hoskinson et al.,
Aust. J. Biotechnol. (1990) 4:166-170; and International
Publication Nos. WO 92/19746, published 12 November 1992;
10 WO 91/02799, published 7 March 1991; WO 90/11298,
published 4 October 1990 and WO 86/07383, published 18
December 1986).

However, attempts have fallen short of
providing adequate immunological sterilization products
15 due to the poor immunogenicity of GnRH peptides and due
to the fact that chemical conjugation protocols are
difficult to control, rendering substantially
heterogenous and poorly-defined GnRH conjugates.
Further, peptide vaccines based on GnRH have met with
20 limited success in providing uniform effects on
individual animal subjects even after repeated
vaccination. In this regard, prior GnRH constructs have
failed to provide a uniformly successful immunological
sterilization vaccine product due to the fact that GnRH
25 is a small, "self" molecule that is not normally
recognized by a subject's immune system, rendering the
molecule poorly immunogenic and inherently unable to
induce a significant immune response against endogenous
GnRH.

30 It is generally recognized that the
immunogenicity of viral antigens, small proteins or
endogenous substances may be significantly increased by
producing immunogenic forms of those molecules comprising
multiple copies of selected epitopes. In this regard,
35 constructs based on two or four repeats of peptides 9-21

of herpes simplex virus type 1 glycoprotein D (Ploeg et al., *J. Immuno. Methods* (1989) 124:211-217), two to six repeats of the antigenic circumsporozoite tetrapeptide NPNA of *Plasmodium falciparum* (Lowell et al., *Science* 5 (1988) 240:800-802), two or four copies of the major immunogenic site of VP1 of foot-and-mouth disease virus (Broekhuijsen et al., *J. gen. Virol.* (1987) 68:3137-3143) and tandem repeats of a GnRH-like polypeptide (Meloan et al., *Vaccine* (1994) 12(8):741-746), have been shown to be 10 effective in increasing the immunogenicity of those molecules.

Furthermore, small proteins or endogenous substances may also be conjugated to a suitable carrier in order to elicit a significant immune response in a 15 challenged host. Suitable carriers are generally polypeptides which include antigenic regions of a protein derived from an infectious material such as a viral surface protein, or a carrier peptide sequence. These carriers serve to non-specifically stimulate T helper 20 cell activity and to help direct antigen to antigen presenting cells for processing and presentation of the peptide at the cell surface in association with molecules of the major histocompatibility complex (MHC).

Several carrier systems have been developed for 25 this purpose. For example, small peptide antigens are often coupled to protein carriers such as keyhole limpet haemocyanin (Bittle et al., *Nature* (1982) 298:30-33), tetanus toxoid (Muller et al., *Proc. Natl. Acad. Sci. U.S.A.* (1982) 79:569-573), ovalbumin, and sperm whale 30 myoglobin, to produce an immune response. These coupling reactions typically result in the incorporation of several moles of peptide antigen per mole of carrier protein. Although presentation of the peptide antigen in multiple copies generally enhances immunogenicity, 35 carriers may elicit strong immunity not relevant to the

peptide antigen and this may inhibit the immune response to the peptide vaccine on secondary immunization (Schutze et al, *J. Immun.* (1985) 135:2319-2322).

Antigen delivery systems have also been based
5 on particulate carriers. For example, preformed particles have been used as platforms onto which antigens can be coupled and incorporated. Systems based on proteosomes (Lowell et al., *Science* (1988) 240:800-802), immune stimulatory complexes (Morein et al., *Nature*
10 (1984) 308:457-460), and viral particles such as HBsAg (Neurath et al., *Mol. Immunol.* (1989) 26:53-62) and rotavirus inner capsid protein (Redmond et al., *Mol. Immunol.* (1991) 28:269-278) have been developed.

Carrier systems have also been devised using
15 recombinantly produced chimeric proteins that self assemble into particles. For example, the yeast retrotransposon, Ty, encodes a series of proteins that assemble into virus like particles (Ty-VLPs; Kingsman, S. M., and A. J. Kingsman *Vacc.* (1988) 6:304-306). Foreign
20 genes have been inserted into the TyA gene and expressed in yeast as a fusion protein. The fusion protein retains the capacity to self assemble into particles of uniform size.

Other chimeric protein particles have been
25 examined such as HBsAg, (Valenzuela et al., *Bio/Technol.* (1985) 3:323-326; U.S. Patent No. 4,722,840; Delpeyroux et al., *Science* (1986) 233:472-475), Hepatitis B core antigen (Clarke et al., *Vaccines 88* (Ed. H. Ginsberg, et al., 1988) pp. 127-131), Poliovirus (Burke et al., *Nature*
30 (1988) 332:81-82), and Tobacco Mosaic Virus (Haynes et al., *Bio/Technol.* (1986) 4:637-641). However, these carriers are restricted in their usefulness by virtue of the limited size of the active agent which may be
35 inserted into the structural protein without interfering with particle assembly.

Finally, chimeric systems have been devised using a *Pasteurella haemolytica* leukotoxin (LKT) polypeptide fused to a selected antigen. See, e.g., International Publication Nos. WO 93/08290, published 29 April 1993 and WO 92/03558, published 5 March 1992, as well as U.S. Patent Nos. 5,238,823 and 5,273,889. Inclusion of a LKT carrier portion in a peptide antigen chimera supplies enhanced immunogenicity to the chimera by providing T-cell epitopes having broad species reactivity, thereby eliciting a T-cell dependent immune response in immunized subjects. In this regard, inducement of adequate T-cell help is essential in the generation of an immune response to the peptide antigen portion of the chimera, particularly where the antigen is an endogenous molecule. However, the use of a leukotoxin polypeptide carrier in combination with multiple epitopes of the GnRH peptide has not heretofore been described.

Disclosure of the Invention

The present invention is based on the construction of novel gene fusions between the *P. haemolytica* leukotoxin gene, variants thereof, and nucleotide sequences encoding multiple GnRH polypeptides. These constructs produce chimeric proteins that display surprisingly enhanced immunogenicity when compared to the immunologic reaction elicited by administration of GnRH alone.

Thus in one embodiment, the present invention is directed to a chimeric protein comprising a leukotoxin polypeptide fused to a multimer consisting essentially of more than one selected GnRH polypeptide, whereby the leukotoxin portion of the chimera acts to increase the immunogenicity of the GnRH polypeptide. More particularly, the GnRH multimer may correspond to more than one copy of a selected GnRH polypeptide or epitope,

or multiple tandem repeats of a selected GnRH polypeptide or epitope. Further, the GnRH multimer may be located at the carboxyl or amino terminals, or at sites internal to the leukotoxin polypeptide. The GnRH multimer may also
5 correspond to a molecule of the general formula GnRH-X-GnRH wherein X is selected from the group consisting of a peptide linkage, an amino acid spacer group and $[GnRH]_n$, where n is greater than or equal to 1, and further wherein "GnRH" may comprise any GnRH polypeptide.

10 Also disclosed are vaccine compositions comprising the chimeric proteins and a pharmaceutically acceptable vehicle, and methods for presenting a selected GnRH multimer to a host subject comprising administering an effective amount of the subject vaccine compositions.

15 In another embodiment, the subject invention is directed to DNA constructs encoding the chimeric proteins. The DNA constructs comprise a first nucleotide sequence encoding a leukotoxin polypeptide operably linked to a second nucleotide sequence encoding more than
20 one copy of a GnRH epitope.

In yet another embodiment, the subject invention is directed to expression cassettes comprised of (a) the DNA constructs above and (b) control sequences that direct the transcription of the construct whereby
25 the constructs can be transcribed and translated in a host cell.

In another embodiment, the invention is directed to host cells transformed with these expression cassettes.

30 Another embodiment of the invention provides a method of producing a recombinant polypeptide. The method comprises (a) providing a population of host cells described above and (b) culturing the population of cells under conditions whereby the polypeptide encoded by the
35 expression cassette is expressed.

These and other embodiments of the present invention will readily occur to those of ordinary skill in the art in view of the disclosure herein.

5 Brief Description of the Figures

Figures 1A and 1B show the nucleotide sequences and amino acid sequences of the GnRH constructs used in the chimeric leukotoxin-GnRH polypeptide gene fusions. Figure 1A depicts GnRH-1 which includes a single copy of
10 a GnRH decapeptide; Figure 1B depicts GnRH-2 which includes four copies of a GnRH decapeptide when n=1, and eight copies of GnRH when n=2, etc.

Figure 2 depicts the structure of Plasmid pAA352 wherein tac is the hybrid trp::lac promoter from
15 *E. coli*; bla represents the β -lactamase gene (ampicillin resistance); ori is the ColE1-based plasmid origin of replication; lktA is the *P. haemolytica* leukotoxin structural gene; and lacI is the *E. coli* lac operon repressor. The direction of transcription/translation of
20 the leukotoxin gene is indicated by the arrow. The size of each component is not drawn to scale.

Figures 3-1 through 3-9 show the nucleotide sequence and predicted amino acid sequence of leukotoxin 352 (LKT 352). Both the structural gene for LKT 352 and
25 the sequences of the flanking vector regions are shown.

Figure 4 shows the structure of Plasmid pCB113 carrying a leukotoxin-GnRH (LKT-GnRH) gene fusion.

Figures 5-1 through 5-8 show the nucleotide sequence and predicted amino acid sequence of the LKT-GnRH chimeric protein from pCB113. The nucleotide
30 sequence and predicted amino acid sequence of the LKT-GnRH chimeric protein from pCB112 are identical to the sequences of the chimeric protein derived from pCB113 except that the sequence for multiple copy GnRH was
35 inserted twice as described above in regard to Figure 4.

Figure 6 shows the structure of Plasmid pCB111 carrying a leukotoxin-GnRH (LKT-GnRH) gene fusion.

Figures 7-1 through 7-5 show the nucleotide sequence and predicted amino acid sequence of the LKT-GnRH chimeric protein from pCB111. The nucleotide sequence and predicted amino acid sequence of the LKT-GnRH chimeric protein from pCB114 are identical to the sequences of the chimeric protein derived from pCB111 except that the sequence for multiple copy GnRH was inserted twice as described above in regard to Figure 6.

Figure 8 shows the nucleotide sequence and predicted amino acid sequence of the blunt end fusion point of the truncated leukotoxin gene of plasmid pCB111 (Figure 8-2), where an internal DNA fragment (of approximately 1300 bp in length) was removed from LKT 352 by digestion with the restriction enzymes *Bst*B1 and *Nae*I (Figure 8-1).

Detailed Description

The practice of the present invention will employ, unless otherwise indicated, conventional techniques of molecular biology, microbiology, virology, recombinant DNA technology, and immunology, which are within the skill of the art. Such techniques are explained fully in the literature. See, e.g., Sambrook, Fritsch & Maniatis, Molecular Cloning: A Laboratory Manual; DNA Cloning, Vols. I and II (D.N. Glover ed.) ; Oligonucleotide Synthesis (M.J. Gait ed.); Nucleic Acid Hybridization (B.D. Hames & S.J. Higgins eds.); Animal Cell Culture (R.K. Freshney ed.); Immobilized Cells and Enzymes (IRL press); B. Perbal, A Practical Guide to Molecular Cloning; the series, Methods In Enzymology (S. Colowick and N. Kaplan eds., Academic Press, Inc.); and Handbook of Experimental Immunology, Vols. I-IV (D.M. Weir and C.C. Blackwell eds., Blackwell Scientific Publications).

A. Definitions

In describing the present invention, the following terms will be employed, and are intended to be defined as indicated below.

5 The term "Gonadotropin releasing hormone" or "GnRH" refers to a decapeptide secreted by the hypothalamus which controls release of both luteinizing hormone (LH) and follicle stimulating hormone (FSH) in vertebrates (Fink, G., *British Medical Bulletin* (1979) 10 35:155-160). The amino acid sequence of GnRH is highly conserved among vertebrates, and especially in mammals. In this regard, GnRH derived from most mammals including human, bovine, porcine and ovine GnRH (formerly designated LHRH) has the amino acid sequence pyroGlu-His-15 Trp-Ser-Tyr-Gly-Leu-Arg-Pro-Gly-NH₂ (Murad et al., *Hormones and Hormone Antagonists*, in The Pharmacological Basis of Therapeutics, Sixth Edition (1980) and Seeburg et al., *Nature* (1984) 311:666-668).

 As used herein a "GnRH polypeptide" includes a 20 molecule derived from a native GnRH sequence, as well as recombinantly produced or chemically synthesized GnRH polypeptides having amino acid sequences which are substantially homologous to native GnRH and which remain immunogenic, as described below. Thus, the term 25 encompasses derivatives and analogues of GnRH including any single or multiple amino acid additions, substitutions and/or deletions occurring internally or at the amino or carboxy terminuses of the peptide. Accordingly, under the invention, a "GnRH polypeptide" 30 includes molecules having the native sequence, molecules such as that depicted in Figure 1A (having an N-terminal Gln residue rather than a pyroGlu residue), and molecules with other amino acid additions, substitutions and/or deletions which retain the ability to elicit formation of 35 antibodies that cross react with naturally occurring

GnRH. Particularly contemplated herein are repeated sequences of GnRH polypeptides such as in the oligomer depicted in Figure 1B (wherein each of the selected GnRH polypeptides comprises a N-terminal Gln substitution, and further wherein every other GnRH polypeptide comprises an Asp residue substitution at position 2). Epitopes of GnRH are also captured by the definition.

The term "epitope" refers to the site on an antigen or hapten to which a specific antibody molecule binds. Since GnRH is a very small molecule, the identification of epitopes thereof which are able to elicit an antibody response is readily accomplished using techniques well known in the art. See, e.g., Geysen et al. *Proc. Natl. Acad. Sci. USA* (1984) 81:3998-4002 (general method of rapidly synthesizing peptides to determine the location of immunogenic epitopes in a given antigen); U.S. Patent No. 4,708,871 (procedures for identifying and chemically synthesizing epitopes of antigens); and Geysen et al., *Molecular Immunology* (1986) 23:709-715 (technique for identifying peptides with high affinity for a given antibody).

As used herein the term "T-cell epitope" refers to a feature of a peptide structure which is capable of inducing T-cell immunity towards the peptide structure or an associated hapten. In this regard, it is accepted in the art that T-cell epitopes comprise linear peptide determinants that assume extended conformations within the peptide-binding cleft of MHC molecules, (Unanue et al., *Science* (1987) 236:551-557). Conversion of polypeptides to MHC class II-associated linear peptide determinants (generally between 5 - 14 amino acids in length) is termed "antigen processing" which is carried out by antigen presenting cells (APCs). More particularly, a T-cell epitope is defined by local features of a short peptide structure, such as primary

amino acid sequence properties involving charge and hydrophobicity, and certain types of secondary structure, such as helicity, that do not depend on the folding of the entire polypeptide. Further, it is believed that short peptides capable of recognition by helper T-cells are generally amphipathic structures comprising a hydrophobic side (for interaction with the MHC molecule) and a hydrophilic side (for interacting with the T-cell receptor), (Margalit et al., *Computer Prediction of T-cell Epitopes*, New Generation Vaccines Marcel-Dekker, Inc, ed. G.C. Woodrow et al., (1990) pp. 109-116) and further that the amphipathic structures have an α -helical configuration (see, e.g., Spouge et al., *J. Immunol.* (1987) 138:204-212; Berkower et al., *J. Immunol.* (1986) 136:2498-2503).

Hence, segments of proteins which include T-cell epitopes can be readily predicted using numerous computer programs. (See e.g., Margalit et al., *Computer Prediction of T-cell Epitopes*, New Generation Vaccines Marcel-Dekker, Inc, ed. G.C. Woodrow et al., (1990) pp. 109-116). Such programs generally compare the amino acid sequence of a peptide to sequences known to induce a T-cell response, and search for patterns of amino acids which are believed to be required for a T-cell epitope.

An "immunogenic protein" or "immunogenic amino acid sequence" is a protein or amino acid sequence, respectively, which elicits an immunological response in a subject to which it is administered. Under the invention, a "GnRH immunogen" refers to a GnRH molecule which, when introduced into a host subject, stimulates an immune response. In this regard, a GnRH immunogen includes a multimer corresponding to more than one selected GnRH polypeptide sequence; and, more particularly, to a multimer having either multiple or tandem repeats of selected GnRH polypeptide sequences,

multiple or tandem repeats of selected GnRH epitopes, or any conceivable combination thereof.

An "immunological response" to an antigen or vaccine is the development in the host of a cellular and/or antibody-mediated immune response to the composition or vaccine of interest. Usually, such a response includes but is not limited to one or more of the following effects; the production of antibodies, B cells, helper T cells, suppressor T cells, and/or cytotoxic T cells and/or $\gamma\delta$ T cells, directed specifically to an antigen or antigens included in the composition or vaccine of interest. An immunological response can be detected using any of several immunoassays well known in the art.

The term "leukotoxin polypeptide" or "LKT polypeptide" intends a polypeptide which includes at least one T-cell epitope and is derived from a protein belonging to the family of molecules characterized by the carboxy-terminus consensus amino acid sequence Gly-Gly-X-Gly-X-Asp (Highlander et al., *DNA* (1989) 8:15-28), where X is Lys, Asp, Val or Asn. Such proteins include, among others, leukotoxins derived from *P. haemolytica* and *Actinobacillus pleuropneumoniae*, as well as *E. coli* alpha hemolysin (Strathdee et al., *Infect. Immun.* (1987) 55:3233-3236; Lo, *Can. J. Vet. Res.* (1990) 54:S33-S35; Welch, *Mol. Microbiol.* (1991) 5:521-528). This family of toxins is known as the "RTX" family of toxins (Lo, *Can. J. Vet. Res.* (1990) 54:S33-S35). In addition, the term "leukotoxin polypeptide" refers to a leukotoxin polypeptide which is chemically synthesized, isolated from an organism expressing the same, or recombinantly produced. Furthermore, the term intends an immunogenic protein having an amino acid sequence substantially homologous to a contiguous amino acid sequence found in the particular native leukotoxin

molecule. Thus, the term includes both full-length and partial sequences, as well as analogues. Although native full-length leukotoxins display leukotoxic activity, the term "leukotoxin" also intends molecules which remain
5 immunogenic yet lack the cytotoxic character of native leukotoxins. The nucleotide sequences and corresponding amino acid sequences for several leukotoxins are known. See, e.g., U.S. Patent Nos. 4,957,739 and 5,055,400; Lo et al., *Infect. Immun.* (1985) 50:667-67; Lo et al.,
10 *Infect. Immun.* (1987) 55:1987-1996; Strathdee et al., *Infect. Immun.* (1987) 55:3233-3236; Highlander et al., *DNA* (1989) 8:15-28; Welch, *Mol. Microbiol.* (1991) 5:521-528. In the chimeras produced according to the present invention, a selected Leukotoxin polypeptide sequence
15 imparts enhanced immunogenicity to a fused GnRH multimer by providing, among other things, T-cell epitopes comprising small peptide segments in the range of five to fourteen amino acids in length which are capable of complexing with MHC class II molecules for presentation
20 to, and activation of, T-helper cells. As discussed further below, these T-cell epitopes occur throughout the leukotoxin molecule and are thought to be concentrated in the N-terminus portions of leukotoxin, i.e., between amino acid residues 1 to 199.

25 As used herein, a leukotoxin polypeptide "which lacks leukotoxic activity" refers to a leukotoxin polypeptide as described above which lacks significant cytotoxicity as compared to a native, full-length leukotoxin (such as the full-length *P. haemolytica*
30 leukotoxin described in U.S. Patent Nos. 5,055,400 and 4,957,739) yet still retains immunogenicity and at least one T-cell epitope. Leukotoxin polypeptides can be tested for leukotoxic activity using any of several known assays such as the lactate dehydrogenase release assay,
35 described by Korzeniewski et al., *Journal of*

Immunological Methods 64:313-320, wherein cytotoxicity is measured by the release of lactate dehydrogenase from bovine neutrophils. A molecule is identified as leukotoxic if it causes a statistically significant release of lactate dehydrogenase when compared to a control non-leukotoxic molecule.

Under the invention, construction of LKT-GnRH chimeras comprising leukotoxin polypeptides which lack leukotoxic activity provides several important benefits. Initially, a leukotoxin polypeptide which lacks leukotoxic activity is desirable since the injection of an active toxin into a subject can result in localized cell death (PMNs and macrophages) and, in turn, cause a severe inflammatory response and abscess at the injection site. In this regard, leukotoxic activity resulting in the killing of macrophages may lead to reduced antigen presentation and hence a suboptimal immune response. The removal of the cytotoxic portion as found in the non-leukotoxic LKT polypeptides used in producing the fusion proteins of the invention also results in a truncated LKT gene which is capable of being expressed at much higher levels than full-length LKT. Further, the use of non-leukotoxic LKT polypeptides in the fusions constructed under the present invention which retain sufficient T-cell antigenicity reduces the overall amount of leukotoxin-GnRH antigen which needs to be administered to a host subject to yield a sufficient B-cell response to the selected GnRH polypeptides. Particular examples of immunogenic leukotoxin polypeptides which lack leukotoxic activity include LKT 352 and LKT 111 which are described in greater detail below.

By "LKT 352" is meant a protein which is derived from the *lktA* gene present in plasmid pAA352 (Figure 2, ATCC Accession No. 68283). The nucleotide sequence and corresponding amino acid sequence of this

gene are described in International Publication No. WO91/15237 and are shown in Figure 3. The gene encodes a truncated leukotoxin, having 931 amino acids and an estimated molecular weight of around 99 kDa, which
5 lacks the cytotoxic portion of the molecule. The truncated gene thus produced is expressed at much higher levels than the full-length molecule (more than 40% of total cell protein versus less than 1% of total cell protein for the full-length form) and is more easily
10 purified. Under the invention, the derived LKT 352 is not necessarily physically derived from the sequence present in plasmid pAA352. Rather, it may be generated in any manner, including for example, by chemical synthesis or recombinant production. In addition, the
15 amino acid sequence of the protein need only be substantially homologous to the depicted sequence. Thus, sequence variations may be present so long as the LKT polypeptide functions to enhance the immunogenicity of antigen with which it is associated yet also lacks
20 leukotoxic activity.

By "LKT 111" is meant a leukotoxin polypeptide which is derived from gene present in plasmid pCB111 (Figure 6, ATCC Accession No. 69748). The nucleotide sequence of this gene and the corresponding amino acid
25 sequence are shown in Figure 7. The gene encodes a shortened version of leukotoxin which was developed from the recombinant leukotoxin gene present in plasmid pAA352 (Figure 2, ATCC Accession No. 68283) by removal of an internal DNA fragment of approximately 1300 bp in length.
30 The LKT 111 polypeptide has an estimated molecular weight of 52 kDa (as compared to the 99 kDa LKT 352 polypeptide), but retains portions of the N-terminus from LKT 352 containing T-cell epitopes which are necessary for sufficient T-cell immunogenicity and portions from
35 the C-terminus from LKT 352 containing convenient

restriction sites for use in producing the fusion proteins of the present invention. Under the invention, the LKT 111 leukotoxin peptide is not necessarily physically derived from the sequence present in plasmid pCB111. Rather, it may be generated in any manner, including for example, by chemical synthesis or recombinant production. In addition, the amino acid sequence of the protein need only be substantially homologous to the depicted sequence. Thus, sequence variations may be present so long as the protein functions to enhance the immunogenicity of antigen with which it is associated and lacks leukotoxicity.

A leukotoxin-GnRH polypeptide chimera displays "increased immunogenicity" when it possesses a greater capacity to elicit an immune response than the corresponding GnRH multimer alone. Such increased immunogenicity can be determined by administering the particular leukotoxin-GnRH polypeptide and GnRH multimer controls to animals and comparing antibody titres against the two using standard assays such as radioimmunoassays and ELISAs, well known in the art.

"Recombinant" proteins or polypeptides refer to polypeptides produced by recombinant DNA techniques; i.e., produced from cells transformed by an exogenous DNA construct encoding the desired polypeptide. "Synthetic" proteins or polypeptides are those prepared by chemical synthesis.

A DNA "coding sequence" or a "nucleotide sequence encoding" a particular protein, is a DNA sequence which is transcribed and translated into a polypeptide *in vivo* or *in vitro* when placed under the control of appropriate regulatory sequences. The boundaries of the coding sequence are determined by a start codon at the 5' (amino) terminus and a translation stop codon at the 3' (carboxy) terminus. A coding

sequence can include, but is not limited to, procaryotic sequences, cDNA from eucaryotic mRNA, genomic DNA sequences from eucaryotic (e.g., mammalian) DNA, and even synthetic DNA sequences. A transcription termination
5 sequence will usually be located 3' to the coding sequence.

DNA "control sequences" refer collectively to promoter sequences, ribosome binding sites, polyadenylation signals, transcription termination
10 sequences, upstream regulatory domains, enhancers, and the like, which collectively provide for the transcription and translation of a coding sequence in a host cell.

A coding sequence is "operably linked to"
15 another coding sequence when RNA polymerase will transcribe the two coding sequences into mRNA, which is then translated into a chimeric polypeptide encoded by the two coding sequences. The coding sequences need not be contiguous to one another so long as the transcribed
20 sequence is ultimately processed to produce the desired chimeric protein. A control sequence is "operably linked to" a coding sequence when it controls the transcription of the coding sequence.

A control sequence "directs the transcription"
25 of a coding sequence in a cell when RNA polymerase will bind the promoter sequence and transcribe the coding sequence into mRNA, which is then translated into the polypeptide encoded by the coding sequence.

A "host cell" is a cell which has been
30 transformed, or is capable of transformation, by an exogenous DNA sequence.

A cell has been "transformed" by exogenous DNA when such exogenous DNA has been introduced inside the cell membrane. Exogenous DNA may or may not be
35 integrated (covalently linked) to chromosomal DNA making

up the genome of the cell. In procaryotes and yeasts, for example, the exogenous DNA may be maintained on an episomal element, such as a plasmid. With respect to eucaryotic cells, a stably transformed cell is one in which the exogenous DNA has become integrated into the chromosome so that it is inherited by daughter cells through chromosome replication. This stability is demonstrated by the ability of the eucaryotic cell to establish cell lines or clones comprised of a population of daughter cell containing the exogenous DNA.

Two DNA or polypeptide sequences are "substantially homologous" when at least about 80% (preferably at least about 90%, and most preferably at least about 95%) of the nucleotides or amino acids match over a defined length of the molecule. DNA sequences that are substantially homologous can be identified in a Southern hybridization experiment under, for example, stringent conditions, as defined for that particular system. Defining appropriate hybridization conditions is within the skill of the art. See, e.g., Sambrook et al., supra; DNA Cloning, vols I & II, supra; Nucleic Acid Hybridization, supra.

A "heterologous" region of a DNA construct is an identifiable segment of DNA within or attached to another DNA molecule that is not found in association with the other molecule in nature. Thus, when the heterologous region encodes a bacterial gene, the gene will usually be flanked by DNA that does not flank the bacterial gene in the genome of the source bacteria. Another example of the heterologous coding sequence is a construct where the coding sequence itself is not found in nature (e.g., synthetic sequences having codons different from the native gene). Allelic variation or naturally occurring mutational events do not give rise to a heterologous region of DNA, as used herein.

By "vertebrate subject" is meant any member of the subphylum chordata, including, without limitation, mammals such as rodents, cattle, pigs, sheep, goats, horses and man; domestic animals such as dogs and cats;
5 birds, including domestic, wild and game birds such as cocks and hens including chickens, turkeys and other gallinaceous birds. The term does not denote a particular age. Thus, both adult and newborn animals are intended to be covered.

10

B. General Methods

Central to the instant invention is the discovery that leukotoxin polypeptides, when coupled to selected GnRH polypeptide repeats (or multimers), are
15 able to confer superior immunogenicity to the associated GnRH moieties. In this regard, leukotoxin polypeptides act as carrier proteins which present selected GnRH multimers to a subject's immune system in a highly immunogenic form. Thus, chimeric proteins constructed
20 under the invention may be formulated into vaccine compositions which provide enhanced immunogenicity to GnRH polypeptides presented therewith. Fusion of the leukotoxin gene to selected GnRH polypeptides also facilitates purification of the chimeric protein from
25 cells expressing the same.

Accordingly, exemplified herein are leukotoxin chimeras which include leukotoxin fused to more than one GnRH peptide sequence. Particularly contemplated
embodiments of the present invention include chimeras
30 comprising a leukotoxin polypeptide fused to a GnRH multimer, wherein said multimer consists essentially of at least one repeating GnRH decapeptide sequence, or at least one repeating unit of a sequence corresponding to at least one epitope of a selected GnRH molecule.
35 Further, the selected GnRH peptide sequences may all be

the same, or may correspond to different derivatives, analogues, variants or epitopes of GnRH so long as they retain the ability to elicit an immune response. A representative nucleotide sequence of a GnRH decapeptide
5 is depicted in Figure 1A. The subject GnRH sequence is modified by the substitution of a glutamine residue at the N-terminal in place of pyroglutamic acid which is found in the native sequence. This particular substitution renders a molecule that retains the native
10 glutamic acid structure but also preserves the uncharged structure of pyroglutamate. Accordingly, the resulting peptide does not require cyclization of the glutamic acid residue and may be produced in the absence of conditions necessary to effect cyclization.

15 Because the GnRH sequence is relatively short, it can easily be generated using synthetic techniques, as described in detail below. Under the invention, a leukotoxin polypeptide sequence is used to confer immunogenicity upon associated GnRH polypeptides (as a
20 carrier protein) in order to help elicit an adequate immune response toward endogenous GnRH in a vertebrate subject. In this manner, immunization with GnRH can regulate fertility in a vaccinated subject by disruption of estrous cycles or spermatogenesis. A detailed
25 discussion of GnRH can be found in U.S. Patent No. 4,975,420.

Further, it is particularly contemplated herein to provide a reliable and effective alternative to
invasive sterilization procedures currently practiced in
30 domestic and farm animal husbandry, such as surgical castration, surgical ovariectomy and the like. Immunosuppression of reproductive activity in vertebrate subjects using leukotoxin-GnRH chimeras constructed according to the present invention provides an effective
35 alternative in that the constructs effect uniform

inactivation of reproductive activity in immunized animals. In this regard, a suitable sterilization vaccine product must serve to uniformly inactivate reproductive capabilities in individual animals in response to a minimum of vaccinations in order to provide a successful alternative to surgical procedures. This feature is particularly important for immunosterilization of herd animals, and particularly where it is desired to immunocastrate male piglets to prevent "boar taint" which is produced by the synthesis of sex steroids in normally functioning testicles of male piglets. See e.g. Meloen et al., *Vaccine* (1994) 12(8):741-746. Prior attempts at developing such a product have not produced uniform results due to the insufficient immunogenicity of GnRH peptides and/or related carrier systems, and the resultant inability of various prior GnRH-based vaccines to induce sufficient immune responses toward endogenous GnRH.

Accordingly, leukotoxin-GnRH polypeptide chimeras contemplated herein comprise a GnRH portion that corresponds to more than one selected GnRH polypeptide sequence in order to render a more immunogenic GnRH peptide antigen. This feature is based on the recognition that endogenous proteins in general may be rendered effective autoantigens by multimerization of their epitopes as described in detail above. More particularly, the GnRH portion of the novel chimeras contemplated herein may comprise either multiple or tandem repeats of selected GnRH sequences, multiple or tandem repeats of selected GnRH epitopes, or any conceivable combination thereof. In this regard, GnRH epitopes may be identified using techniques as described in detail above, or fragments of GnRH proteins may be tested for immunogenicity and active fragments used in compositions in lieu of the entire polypeptide. The

sequence of a particularly contemplated GnRH portion under the present invention is depicted in Figure 1B wherein four GnRH sequences, indicated at (1), (2), (3) and (4) respectively, are separated by triplet amino acid spacer sequences comprising various combinations of serine and glycine residues. In the subject oligomer, every other GnRH sequence (those indicated at (2) and (4), respectively) contains a non-conservative amino acid substitution at the second position of the GnRH decapeptide comprising an Asp residue in place of the His residue found in the native GnRH sequence. The alternating GnRH multimeric sequence thus produced renders a highly immunogenic GnRH antigen peptide for use in the fusion proteins of the invention. Other GnRH analogues corresponding to any single or multiple amino acid additions, substitutions and/or deletions are also particularly contemplated herein for use in either repetitive or alternating multimeric sequences.

Furthermore, the particular GnRH portion depicted in Figure 1B contains spacer sequences between the GnRH moieties. The present invention particularly contemplates the strategic use of various spacer sequences between selected GnRH polypeptides in order to confer increased immunogenicity on the subject constructs. Accordingly, under the invention, a selected spacer sequence may encode a wide variety of moieties of one or more amino acids in length. Selected spacer groups may preferably provide enzyme cleavage sites so that the expressed chimera can be processed by proteolytic enzymes in vivo (by APC's or the like) to yield a number of peptides —each of which contain at least one T-cell epitope derived from the carrier portion (leukotoxin portion)— and which are preferably fused to a substantially complete GnRH polypeptide sequence. Further, spacer groups may be constructed so that the

junction region between selected GnRH moieties comprises a clearly foreign sequence to the immunized subject, thereby conferring enhanced immunogenicity upon the associated GnRH peptides. Additionally, spacer sequences
5 may be constructed so as to provide T-cell antigenicity, such as sequences which encode amphipathic and/or α -helical peptide sequences which are generally regarded in the art as providing immunogenic helper T-cell epitopes. In this regard, the choice of particular T-cell epitopes
10 to be provided by such spacer sequences may vary depending on the particular vertebrate species to be vaccinated. Although, particular GnRH portions are exemplified which include spacer sequences, it is also contemplated herein to provide a GnRH multimer comprising
15 directly adjacent GnRH sequences (without intervening spacer sequences).

The leukotoxin-GnRH polypeptide complex can be conveniently produced recombinantly as a chimeric protein. The GnRH portion of the chimera can be fused
20 either 5' or 3' to the leukotoxin portion of the molecule, or the GnRH portion may be located at sites internal to the leukotoxin molecule. The nucleotide sequence coding for full-length *P. haemolytica* A1 leukotoxin has been determined. See, e.g., Lo, *Infect.*
25 *Immun.* (1987) 55:1987-1996; U.S. Patent No. 5,055,400. Additionally, several variant leukotoxin gene sequences are disclosed herein.

Similarly, the coding sequences for porcine, bovine and ovine GnRH have been determined, (Murad et
30 al., *Hormones and Hormone Antagonists*, in The Pharmacological Basis of Therapeutics, Sixth Edition (1980)), and the cDNA for human GnRH has been cloned so that its sequence has been well established (Seeburg et
al., *Nature* (1984) 311:666-668). Additional GnRH
35 polypeptides of known sequences have been disclosed, such

as the GnRH molecule occurring in salmon and chickens (International Publication No. WO 86/07383, published 18 December 1986). In this regard, it is noted that GnRH is highly conserved in vertebrates, particularly in mammals; and further that porcine, bovine, ovine and human GnRH sequences are identical to one another. The desired leukotoxin and GnRH genes can be cloned, isolated and ligated together using recombinant techniques generally known in the art. See, e.g., Sambrook et al., supra.

Alternatively, DNA sequences encoding the chimeric proteins can be prepared synthetically rather than cloned. The DNA sequence can be designed with the appropriate codons for the particular amino acid sequence. In general, one will select preferred codons for the intended host if the sequence will be used for expression. The complete sequence is assembled from overlapping oligonucleotides prepared by standard methods and assembled into a complete coding sequence. See, e.g., Edge, *Nature* (1981) 292:756; Nambair et al. *Science* (1984) 223:1299; Jay et al. *J. Biol. Chem.* (1984) 259:6311.

Once coding sequences for the chimeric proteins have been prepared or isolated, they can be cloned into any suitable vector or replicon. Numerous cloning vectors are known to those of skill in the art, and the selection of an appropriate cloning vector is a matter of choice. Examples of recombinant DNA vectors for cloning and host cells which they can transform include the bacteriophage lambda (*E. coli*), pBR322 (*E. coli*), pACYC177 (*E. coli*), pKT230 (gram-negative bacteria), pGV1106 (gram-negative bacteria), pLAFR1 (gram-negative bacteria), pME290 (non-*E. coli* gram-negative bacteria), pHV14 (*E. coli* and *Bacillus subtilis*), pBD9 (*Bacillus*), pIJ61 (*Streptomyces*), pUC6 (*Streptomyces*), YIp5 (*Saccharomyces*), YCp19 (*Saccharomyces*) and bovine

papilloma virus (mammalian cells). See, generally, DNA Cloning: Vols. I & II, supra; T. Maniatis et al., supra; B. Perbal, supra.

5 The fusion gene can be placed under the control
of a promoter, ribosome binding site (for bacterial
expression) and, optionally, an operator (collectively
referred to herein as "control" elements), so that the
DNA sequence encoding the chimeric protein is transcribed
10 into RNA in the host cell transformed by a vector
containing this expression construction. The coding
sequence may or may not contain a signal peptide or
leader sequence. The chimeric proteins of the present
invention can be expressed using, for example, native *P.*
haemolytica promoter, the *E. coli* tac promoter or the
15 protein A gene (*spa*) promoter and signal sequence.
Leader sequences can be removed by the bacterial host in
post-translational processing. See, e.g., U.S. Patent
Nos. 4,431,739; 4,425,437; 4,338,397.

20 In addition to control sequences, it may be
desirable to add regulatory sequences which allow for
regulation of the expression of the protein sequences
relative to the growth of the host cell. Regulatory
sequences are known to those of skill in the art, and
examples include those which cause the expression of a
25 gene to be turned on or off in response to a chemical or
physical stimulus, including the presence of a regulatory
compound. Other types of regulatory elements may also be
present in the vector, for example, enhancer sequences.

30 An expression vector is constructed so that the
particular fusion coding sequence is located in the
vector with the appropriate regulatory sequences, the
positioning and orientation of the coding sequence with
respect to the control sequences being such that the
coding sequence is transcribed under the "control" of the
35 control sequences (i.e., RNA polymerase which binds to

the DNA molecule at the control sequences transcribes the coding sequence). Modification of the sequences encoding the particular chimeric protein of interest may be desirable to achieve this end. For example, in some cases it may be necessary to modify the sequence so that it may be attached to the control sequences with the appropriate orientation; i.e., to maintain the reading frame. The control sequences and other regulatory sequences may be ligated to the coding sequence prior to insertion into a vector, such as the cloning vectors described above. Alternatively, the coding sequence can be cloned directly into an expression vector which already contains the control sequences and an appropriate restriction site.

In some cases, it may be desirable to add sequences which cause the secretion of the polypeptide from the host organism, with subsequent cleavage of the secretory signal. It may also be desirable to produce mutants or analogues of the chimeric proteins of interest. Mutants or analogues may be prepared by the deletion of a portion of the sequence encoding the protein, by insertion of a sequence, and/or by substitution of one or more nucleotides within the sequence. Techniques for modifying nucleotide sequences, such as site-directed mutagenesis, are well known to those skilled in the art. See, e.g., T. Maniatis et al., supra; DNA Cloning, Vols. I and II, supra; Nucleic Acid Hybridization, supra.

A number of procaryotic expression vectors are known in the art. See, e.g., U.S. Patent Nos. 4,440,859; 4,436,815; 4,431,740; 4,431,739; 4,428,941; 4,425,437; 4,418,149; 4,411,994; 4,366,246; 4,342,832; see also U.K. Patent Applications GB 2,121,054; GB 2,008,123; GB 2,007,675; and European Patent Application 103,395. Yeast expression vectors are also known in the art. See,

e.g., U.S. Patent Nos. 4,446,235; 4,443,539; 4,430,428; see also European Patent Applications 103,409; 100,561; 96,491.

5 Depending on the expression system and host selected, the proteins of the present invention are produced by growing host cells transformed by an expression vector described above under conditions whereby the protein of interest is expressed. The chimeric protein is then isolated from the host cells and purified. If
10 the expression system secretes the protein into growth media, the protein can be purified directly from the media. If the protein is not secreted, it is isolated from cell lysates. The selection of the appropriate growth conditions and recovery methods are within the
15 skill of the art.

The chimeric proteins of the present invention may also be produced by chemical synthesis such as solid phase peptide synthesis, based on the determined amino acid sequences. Such methods are known to those skilled
20 in the art. See, e.g., J. M. Stewart and J. D. Young, *Solid Phase Peptide Synthesis*, 2nd Ed., Pierce Chemical Co., Rockford, IL (1984) and G. Barany and R. B. Merrifield, *The Peptides: Analysis, Synthesis, Biology*, editors E. Gross and J. Meienhofer, Vol. 2, Academic
25 Press, New York, (1980), pp. 3-254, for solid phase peptide synthesis techniques; and M. Bodansky, *Principles of Peptide Synthesis*, Springer-Verlag, Berlin (1984) and E. Gross and J. Meienhofer, Eds., *The Peptides: Analysis, Synthesis, Biology*, supra, Vol. 1, for classical solution
30 synthesis.

Subjects can be immunized with chimeric proteins constructed according to the present invention by administration of vaccine compositions which include said proteins. Prior to immunization, it may be
35 desirable to further increase the immunogenicity of the

particular chimeric protein. This can be accomplished in any one of several ways known to those of skill in the art. For example, the leukotoxin-GnRH polypeptide fusion protein may be administered linked to a secondary
5 carrier. For example, a fragment may be conjugated with a macromolecular carrier. Suitable carriers are typically large, slowly metabolized macromolecule such as: proteins; polysaccharides, such as sepharose, agarose, cellulose, cellulose beads and the like;
10 polymeric amino acids such as polyglutamic acid, polylysine, and the like; amino acid copolymers; and inactive virus particles. Especially useful protein substrates are serum albumins, keyhole limpet hemocyanin, immunoglobulin molecules, thyroglobulin, ovalbumin, and
15 other proteins well known to those skilled in the art.

The protein substrates may be used in their native form or their functional group content may be modified by, for example, succinylation of lysine residues or reaction with Cys-thiolactone. A sulfhydryl
20 group may also be incorporated into the carrier (or selected GnRH polypeptides) by, for example, reaction of amino functions with 2-iminothiolane or the N-hydroxysuccinimide ester of 3-(4-dithiopyridyl propionate. Suitable carriers may also be modified to
25 incorporate spacer arms (such as hexamethylene diamine or other bifunctional molecules of similar size) for attachment of peptides.

Other suitable carriers for the chimeric proteins of the present invention include VP6
30 polypeptides of rotaviruses, or functional fragments thereof, as disclosed in U.S. Patent No. 5,071,651. Also useful is a fusion product of a viral protein and a leukotoxin-GnRH immunogen, where that fusion product is made by methods disclosed in U.S. Patent No. 4,722,840.
35 Still other suitable carriers include cells, such as

lymphocytes, since presentation in this form mimics the natural mode of presentation in the subject, which gives rise to the immunized state. Alternatively, the fusion proteins of the present invention may be coupled to
5 erythrocytes, preferably the subject's own erythrocytes. Methods of coupling peptides to proteins or cells are known to those of skill in the art.

The novel chimeric proteins of the instant invention can also be administered via a carrier virus
10 which expresses the same. Carrier viruses which will find use with the instant invention include but are not limited to the vaccinia and other pox viruses, adenovirus, and herpes virus. By way of example, vaccinia virus recombinants expressing the novel chimeric
15 proteins can be constructed as follows. The DNA encoding the particular leukotoxin-GnRH chimeric protein is first inserted into an appropriate vector so that it is adjacent to a vaccinia promoter and flanking vaccinia DNA sequences, such as the sequence encoding thymidine kinase
20 (TK). This vector is then used to transfect cells which are simultaneously infected with vaccinia. Homologous recombination serves to insert the vaccinia promoter plus the gene encoding the instant chimeric protein into the viral genome. The resulting TK-recombinant can be
25 selected by culturing the cells in the presence of 5-bromodeoxyuridine and picking viral plaques resistant thereto.

It is also possible to immunize a subject with chimeric proteins produced according to the present
30 invention, either administered alone, or mixed with a pharmaceutically acceptable vehicle or excipient. Typically, vaccines are prepared as injectables, either as liquid solutions or suspensions; solid forms suitable for solution in, or suspension in, liquid vehicles prior
35 to injection may also be prepared. The preparation may

also be emulsified or the active ingredient encapsulated in liposome vehicles. The active immunogenic ingredient is often mixed with vehicles containing excipients which are pharmaceutically acceptable and compatible with the active ingredient. Suitable vehicles are, for example, water, saline, dextrose, glycerol, ethanol, or the like, and combinations thereof. In addition, if desired, the vehicle may contain minor amounts of auxiliary substances such as wetting or emulsifying agents, pH buffering agents, or adjuvants which enhance the effectiveness of the vaccine. Adjuvants may include for example, muramyl dipeptides, avridine, aluminum hydroxide, oils, saponins and other substances known in the art. Actual methods of preparing such dosage forms are known, or will be apparent, to those skilled in the art. See, e.g., Remington's Pharmaceutical Sciences, Mack Publishing Company, Easton, Pennsylvania, 18th edition, 1990. The composition or formulation to be administered will, in any event, contain a quantity of the protein adequate to achieve the desired immunized state in the subject being treated.

Additional vaccine formulations which are suitable for other modes of administration include suppositories and, in some cases, aerosol, intranasal, oral formulations, and sustained release formulations. For suppositories, the vehicle composition will include traditional binders and carriers, such as, polyalkaline glycols, or triglycerides. Such suppositories may be formed from mixtures containing the active ingredient in the range of about 0.5% to about 10% (w/w), preferably about 1% to about 2%. Oral vehicles include such normally employed excipients as, for example, pharmaceutical grades of mannitol, lactose, starch, magnesium, stearate, sodium saccharin cellulose, magnesium carbonate, and the like. These oral vaccine compositions may be taken in the form of solutions,

suspensions, tablets, pills, capsules, sustained release formulations, or powders, and contain from about 1% to about 30% of the active ingredient, preferably about 2% to about 20%.

5 Intranasal formulations will usually include vehicles that neither cause irritation to the nasal mucosa nor significantly disturb ciliary function. Diluents such as water, aqueous saline or other known substances can be employed with the subject invention.
10 The nasal formulations may also contain preservatives such as, but not limited to, chlorobutanol and benzalkonium chloride. A surfactant may be present to enhance absorption of the subject proteins by the nasal mucosa.

15 Controlled or sustained release formulations are made by incorporating the chimeric proteins into carriers or vehicles such as liposomes, nonresorbable impermeable polymers such as ethylenevinyl acetate copolymers and Hytrel® copolymers, swellable polymers
20 such as hydrogels, or resorbable polymers such as collagen and certain polyacids or polyesters such as those used to make resorbable sutures. The chimeric proteins can also be presented using implanted mini-pumps, well known in the art.

25 Furthermore, the chimeric proteins (or complexes thereof) may be formulated into vaccine compositions in either neutral or salt forms. Pharmaceutically acceptable salts include the acid
30 addition salts (formed with the free amino groups of the active polypeptides) and which are formed with inorganic acids such as, for example, hydrochloric or phosphoric acids, or such organic acids as acetic, oxalic, tartaric, mandelic, and the like. Salts formed from free carboxyl groups may also be derived from inorganic bases such as,
35 for example, sodium, potassium, ammonium, calcium, or

ferric hydroxides, and such organic bases as isopropylamine, trimethylamine, 2-ethylamino ethanol, histidine, procaine, and the like.

To immunize a subject, a selected GnRH-leukotoxin chimera is administered parenterally, usually by intramuscular injection in an appropriate vehicle. Other modes of administration, however, such as subcutaneous, intravenous injection and intranasal delivery, are also acceptable. Injectable vaccine formulations will contain an effective amount of the active ingredient in a vehicle, the exact amount being readily determined by one skilled in the art. The active ingredient may typically range from about 1% to about 95% (w/w) of the composition, or even higher or lower if appropriate. The quantity to be administered depends on the animal to be treated, the capacity of the animal's immune system to synthesize antibodies, and the degree of protection desired.

With the present vaccine formulations, approximately 1 μ g to 1 mg, more generally 5 μ g to 200 μ g of GnRH polypeptide per ml of injected solution, should be adequate to raise an immunological response when administered. In this regard, the ratio of GnRH to leukotoxin in the Leukotoxin-GnRH antigens of the subject vaccine formulations will vary based on the particular leukotoxin and GnRH polypeptide moieties selected to construct those molecules. More particularly, in the leukotoxin-GnRH polypeptides used in producing the vaccine formulations under the invention, there will be about 1 to 25% GnRH, preferably about 3 to 20% and most preferably about 7 to 17% GnRH polypeptide per fusion molecule. Increases in the percentage of GnRH present in the LKT-GnRH antigens reduces the amount of total antigen which must be administered to a subject in order to elicit an effective B-cell response to GnRH. Effective

dosages can be readily established by one of ordinary skill in the art through routine trials establishing dose response curves. The subject is immunized by administration of the particular leukotoxin-GnRH polypeptide in at least one dose, and preferably two doses. Moreover, the animal may be administered as many doses as is required to maintain a state of immunity.

Below are examples of specific embodiments for carrying out the present invention. The examples are offered for illustrative purposes only, and are not intended to limit the scope of the present invention in any way.

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C. ExperimentalMaterials and Methods

Enzymes were purchased from commercial sources, and used according to the manufacturers' directions. Radionucleotides and nitrocellulose filters were also purchased from commercial sources.

In the cloning of DNA fragments, except where noted, all DNA manipulations were done according to standard procedures. See Sambrook et al., supra. Restriction enzymes, T₄ DNA ligase, *E. coli*, DNA polymerase I, Klenow fragment, and other biological reagents were purchased from commercial suppliers and used according to the manufacturers' directions. Double-stranded DNA fragments were separated on agarose gels.

cDNA and genomic libraries were prepared by standard techniques in pUC13 and the bacteriophage lambda gt11, respectively. See DNA CLONING: Vols I and II, supra.

P. haemolytica biotype A, serotype 1 ("A1") strain B122 was isolated from the lung of a calf which died of pneumonic pasteurellosis and was stored at -70°C in defibrinated blood. Routine propagation was carried out on blood agar plates or in brain heart infusion broth (Difco Laboratories, Detroit, MI) supplemented with 5% (v/v) horse serum (Gibco Canada Ltd., Burlington, Canada). All cultures were incubated at 37°C.

Example 1

30 Isolation of *P. haemolytica* Leukotoxin Gene

To isolate the leukotoxin gene, gene libraries of *P. haemolytica* A1 (strain B122) were constructed using standard techniques. See, Lo et al., *Infect. Immun.*, supra; DNA CLONING: Vols. I and II, supra; and Sambrook et al., supra. A genomic library was constructed in the

plasmid vector pUC13 and a DNA library constructed in the bacteriophage lambda gt11. The resulting clones were used to transform *E. coli* and individual colonies were pooled and screened for reaction with serum from a calf which had survived a *P. haemolytica* infection and that had been boosted with a concentrated culture supernatant of *P. haemolytica* to increase anti-leukotoxin antibody levels. Positive colonies were screened for their ability to produce leukotoxin by incubating cell lysates with bovine neutrophils and subsequently measuring release of lactate dehydrogenase from the latter.

Several positive colonies were identified and these recombinants were analyzed by restriction endonuclease mapping. One clone appeared to be identical to a leukotoxin gene cloned previously. See, Lo et al., *Infect. Immun.*, supra. To confirm this, smaller fragments were re-cloned and the restriction maps compared. It was determined that approximately 4 kilobase pairs of DNA had been cloned. Progressively larger clones were isolated by carrying out a chromosome walk (5' to 3' direction) in order to isolate full-length recombinants which were approximately 8 kb in length. The final construct was termed pAA114. This construct contained the entire leukotoxin gene sequence.

lktA, a *MaeI* restriction endonuclease fragment from pAA114 which contained the entire leukotoxin gene, was treated with the Klenow fragment of DNA polymerase I plus nucleotide triphosphates and ligated into the *SmaI* site of the cloning vector pUC13. This plasmid was named pAA179. From this, two expression constructs were made in the ptac-based vector pGH432:lacI digested with *SmaI*. One, pAA342, consisted of the 5'-*AhaIII* fragment of the lktA gene while the other, pAA345, contained the entire *MaeI* fragment described above. The clone pAA342 expressed a truncated leukotoxin peptide at high levels

while pAA345 expressed full length leukotoxin at very low levels. Therefore, the 3' end of the lktA gene (StyI BamHI fragment from pAA345) was ligated to StyI BamHI-digested pAA342, yielding the plasmid pAA352. The
5 structure of pAA352 is shown in Figure 2 and the nucleotide sequence and predicted amino acid sequence of *P. haemolytica* leukotoxin produced from the pAA352 construct (hereinafter LKT 352) is shown in Figure 3.

10

Example 2

Construction of LKT-GnRH Fusions

Representative LKT-GnRH fusions were constructed as follows. Oligonucleotides containing sequences corresponding to single copy GnRH and GnRH as
15 four multiple repeats were constructed on a Pharmacia Gene Assembler using standard phosphoramidite chemistry. The sequences of these oligonucleotides are shown in Figures 1A and 1B. The subject oligonucleotides were annealed and ligated into the vector pAA352 (ATCC No.
20 68283, and described above), which had been digested with the restriction endonuclease BamHI. This vector contains the *P. haemolytica* leukotoxin gene. The ligated DNA was used to transform *E. coli* strain MH3000. Transformants containing the oligonucleotide inserts were identified by
25 restriction endonuclease mapping.

An eight copy GnRH tandem repeat sequence was prepared by annealing the four copy GnRH oligonucleotides and ligating them into a vector which had been digested with the restriction endonuclease BamHI. The oligomers
30 were designed to disable the upstream BamHI site when inserted and to ensure that the insertion of additional copies of the oligomer would be oriented in the proper reading frame. The sequence of the subject oligonucleotide is shown in Figure 1B. Plasmid DNA from
35 the *E. coli* MH3000 strain was then isolated and used to

transform the strain JM105. The recombinant plasmids were designated pCB113 (LKT 352:4 copy GnRH, ATCC Accession No. 69749) and pCB112 (LKT 352:8 copy GnRH). Recombinant plasmid pCB113 is shown in Figure 4, plasmid pCB112 is identical to pCB113 except that the multiple copy GnRH sequence (corresponding to the oligomer of Figure 1B) was inserted twice as described above. The nucleotide sequence of the recombinant LKT-GnRH fusion of pCB113 is shown in Figure 5. The nucleotide sequence of the recombinant LKT-GnRH fusion pCB112 is identical except that the multiple copy GnRH sequence was inserted twice.

Example 3

Construction of Shortened LKT Carrier Peptide

A shortened version of the recombinant leukotoxin peptide was constructed from the recombinant gene present on the plasmid pAA352 (as described above). The shortened LKT gene was produced by deleting an internal DNA fragment of approximately 1300 bp in length from the recombinant LKT gene as follows.

The plasmid pCB113, (ATCC Accession No. 69749) which includes the LKT 352 polypeptide fused to four copies of the GnRH polypeptide, was digested with the restriction enzyme *Bst*B1 (New England Biolabs). The resultant linearized plasmid was then digested with mung-bean nuclease (Pharmacia) to remove the single stranded protruding termini produced by the *Bst*B1 digestion. The blunted DNA was then digested with the restriction enzyme *Nae*I (New England Biolabs), and the digested DNA was loaded onto a 1% agarose gel where the DNA fragments were separated by electrophoresis. A large DNA fragment of approximately 6190 bp was isolated and purified from the agarose gel using a Gene Clean kit (Bio 101), and the purified fragment was allowed to ligate to itself using

bacteriophage T4 DNA ligase (Pharmacia). The resulting ligation mix was used to transform competent *E. coli* JM105 cells, and positive clones were identified by their ability to produce an aggregate protein having a molecular weight of approximately 57 KDa. The recombinant plasmid thus formed was designated pCB111, (ATCC Accession No. 69748), and produces a shortened leukotoxin polypeptide (hereinafter referred to as LKT 111) fused to four copies of GnRH polypeptide. The structure of pCB111 is shown in Figure 6. Plasmid pCB114 is identical to pCB111 except that the multiple copy GnRH sequence (corresponding to the oligomer of Figure 1B) was inserted twice. The nucleotide sequence of the recombinant LKT-GnRH fusion of pCB111 is shown in Figure 7, the nucleotide sequence of the recombinant LKT-GnRH fusion of pCB114 is identical except that the multiple copy GnRH sequence was inserted twice.

The nucleotide sequence of the ligation fusion point of the subject clones has been confirmed by sequencing with a bacteriophage T7 polymerase sequencing kit (Pharmacia). The nucleotide sequences of these fusion points are shown in Figure 8.

Example 4

Purification of LKT-antigen Fusions

The recombinant LKT-GnRH fusions from Examples 2 and 3 were purified using the following procedure. For each fusion, five to ten colonies of the transformed *E. coli* strains were inoculated into 10 ml of TB broth supplemented with 100 micrograms/ml of ampicillin and incubated at 37°C for 6 hours on a G10 shaker, 220 rpm. Four ml of this culture was diluted into each of two baffled Fernbach flasks containing 400 ml of TB broth + ampicillin and incubated overnight as described above. Cells were harvested by centrifugation for 10 minutes at

4,000 rpm in polypropylene bottles, 500 ml volume, using a Sorvall GS3 rotor. The pellet was resuspended in an equal volume of TB broth containing ampicillin which had been prewarmed to 37°C (i.e., 2 x 400 ml), and the cells
5 were incubated for 2 hours as described above.

3.2 ml of isopropyl-B,D-thiogalactopyranoside (IPTG, Gibco/BRL), 500 mM in water (final concentration = 4 mM), was added to each culture in order to induce synthesis of the recombinant fusion proteins. Cultures
10 were incubated for two hours. Cells were harvested by centrifugation as described above, resuspended in 30 ml of 50 mM Tris-hydrochloride, 25% (w/v) sucrose, pH 8.0, and frozen at -70°C. The frozen cells were thawed at room temperature after 60 minutes at -70°C, and 5 ml of
15 lysozyme (Sigma, 20 mg/ml in 250 mM Tris-HCl, pH 8.0) was added. The mixture was vortexed at high speed for 10 seconds and then placed on ice for 15 minutes. The cells were then added to 500 ml of lysis buffer in a 1000 ml beaker and mixed by stirring with a 2 ml pipette. The
20 beaker containing the lysed cell suspension was placed on ice and sonicated for a total of 2.5 minutes (5-30 second bursts with 1 minute cooling between each) with a Braun sonicator, large probe, set at 100 watts power. Equal volumes of the solution were placed in Teflon SS34
25 centrifuge tubes and centrifuged for 20 minutes at 10,000 rpm in a Sorvall SS34 rotor. The pellets were resuspended in a total of 100 ml of sterile double distilled water by vortexing at high speed, and the centrifugation step repeated. Supernatants were
30 discarded and the pellets combined in 20 ml of 10 mM Tris-HCl, 150 mM NaCl, pH 8.0 (Tris-buffered saline) and the suspension frozen overnight at -20°C.

The recombinant suspension was thawed at room temperature and added to 100 ml of 8 M Guanidine HCl
35 (Sigma) in Tris-buffered saline and mixed vigorously. A

magnetic stir bar was placed in the bottle and the solubilized sample was mixed at room temperature for 30 minutes. The solution was transferred to a 2000 ml Erlenmyer flask and 1200 ml of Tris-buffered saline was added quickly. This mixture was stirred at room temperature for an additional 2 hours. 500 ml aliquots were placed in dialysis bags (Spectrum, 63.7 mm diameter, 6,000-8,000 MW cutoff, #132670, from Fisher scientific) and these were placed in 4,000 ml beakers containing 3,500 ml of Tris-buffered saline + 0.5 M Guanidine HCl. The beakers were placed in a 4°C room on a magnetic stirrer overnight after which dialysis buffer was replaced with Tris-buffered saline + 0.1 M Guanidine HCl and dialysis continued for 12 hours. The buffer was then replaced with Tris-buffered saline + 0.05 M Guanidine HCl and dialysis continued overnight. The buffer was replaced with Tris-buffered saline (no guanidine), and dialysis continued for 12 hours. This was repeated three more times. The final solution was poured into a 2000 ml plastic roller bottle (Corning) and 13 ml of 100 mM PMSF (in ethanol) was added to inhibit protease activity. The solution was stored at -20°C in 100 ml aliquots.

To confirm that the fusion proteins had been isolated, aliquots of each preparation were diluted 20-fold in double distilled water, mixed with an equal volume of SDS-PAGE sample buffer, placed in a boiling water bath for five minutes and run through 12% polyacrylamide gels. Recombinant leukotoxin controls were also run.

All fusion proteins were expressed at high levels as inclusion bodies. The predicted molecular weights based on the DNA sequences of the fusion proteins were 104,869 (LKT 352::4 copy GnRH, from pCB113); 110,392 (LKT 352::8 copy GnRH, from pCB112); 57,542 (LKT 111::4 copy GnRH, from pCB111); and 63,241 (LKT 111::8 copy GnRH

from pCB114). The predicted molecular weight of the recombinant LKT 352 molecule was 99,338, and the predicted molecular weight of the recombinant LKT 111 molecule was 51,843.

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Example 5

In Vivo Immunologic Activity of LKT-GnRH Fusions

To test for the ability of LKT-GnRH fusions to induce an anti-GnRH immunological response in vivo, and to compare this response to other GnRH carrier conjugates, the following vaccination trial was performed. Three groups of 8 male pigs, approximately 8 weeks of age (35-50 kg) were used which were Specific Pathogen Free. The animals were maintained in a minimal disease facility and were vaccinated on days 0 and 21 of the trial with the following formulations:

Group 1 -- placebo which consisted of saline formulated in Emulsigen Plus adjuvant containing 15 mg of DDA (2 ml);

Group 2 -- LKT 352-GnRH (250 µg LKT, prepared as described in the previous examples) formulated in the same adjuvant (2 ml);

Group 3 -- VP6-GnRH, 0.5 µg VP6 and 5 µg GnRH, formulated in the same adjuvant (2 ml). The VP6 preparation was made as described in U.S. Patent No. 5,071,651, using the binding peptide described therein.

Blood samples were taken on days 0, 21 and 35, allowed to clot, centrifuged at 1500 g, and the serum removed. The serum antibody titres against GnRH were measured using the RIA procedure of Silversides et al., *J. Reprod. Immunol.* (1985) 7:171-184.

The results of this trial indicated that only those animals immunized with the LKT 352-GnRH formulation produced significant titres against GnRH (titres >1:70).

Neither the placebo nor the VP6-GnRH groups produced

anti-GnRH titres. Previously, multiple vaccinations with doses of GnRH of more than 100 µg, conjugated to other carrier proteins, were required to induce anti-hormone titres. These results indicate that the LKT-GnRH carrier system provides a greatly improved immunogen over prior carrier systems.

Example 6

In Vivo Immunologic Effect of Multiple Tandem GnRH Repeats Ligated to LKT

To test for the ability of recombinant LKT-GnRH fusion proteins containing multiple GnRH polypeptide repeats to induce an anti-GnRH immunological response in vivo, the following vaccination trial was performed.

Cultures of *E. coli* containing plasmids pCB113 and pCB175 (having 4 and 8 copies of GnRH ligated to LKT 352, respectively) and a plasmid having 1 copy of GnRH ligated to LKT 352 were prepared as described above. Vaccines from each of the above cultures were formulated to contain the equivalent of 5 µg of GnRH in 0.2 ml of Emulsigen Plus. Three groups of 10 female mice were given two subcutaneous injections 23 days apart and blood samples were collected at days 23, 35 and 44 after the primary injection. Serum antibody titres against GnRH were measured at final dilutions of 1:100 and 1:1000 using a standard radioimmunoassay procedure. If less than 5% of the iodinated GnRH was bound, antibody was deemed to be undetectable. The antibody titres thus obtained are summarized in the Table 1.

The results of this study indicate that equal doses of GnRH presented as multiple tandem repeats (four or eight copy GnRH) gave a dramatic improvement in antibody production over single copy GnRH (as measured by binding to iodinated native GnRH). Further, the above results indicate that a fusion protein comprising a four

copy GnRH tandem repeat ligated to LKT 352 represents an optimal immunogenic GnRH antigen form, although immunogenicity may be influenced by dose or subject species.

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Sample Day	Group 1				Group 2				Group 3			
	LKT 352::1 Copy GnRH				LKT 352::4 Copy GnRH				LKT 352::8 Copy GnRH			
	No. responding		mean response (%)*		No. responding		mean response (%)*		No. responding		mean response (%)*	
	1:100	1:1000	1:100	1:1000	1:100	1:1000	1:100	1:1000	1:100	1:1000	1:100	1:1000
23	0	0	-	-	3	1	16	9	2	0	33	-
35	2	2	45	20	9	9	75	30	7	5	48	41
44	2	2	60	39	10	10	55	43	8	7	57	46

*mean response is the average binding of 125 -GnRH of only those animals with binding in excess of 5%.

Table 1

Example 7

In Vivo Immunologic Activity and Biologic Effect
of LKT 352::GnRH and LKT 111::GnRH Fusions

To test the ability of fusion proteins
5 comprising multiple tandem repeats of GnRH (ligated to
either LKT 352 or LKT 111) to elicit an anti-GnRH
immunological response in vivo and to manifest a biologic
effect in vivo, the following vaccination trial was
preformed. Cultures of *E. coli* containing plasmids
10 pCB113 and pCB111 (4 copy GnRH ligated to LKT 352 or LKT
111, respectively) were prepared as described above.
Vaccines from each of the above cultures were formulated
to contain the equivalent of 5 µg of GnRH in 0.2 ml of
VSA-3 adjuvant, (a modified Emulsigen Plus adjuvant),
15 with a control vaccine comprising 0.2 ml of the adjuvant
also being prepared. Three groups of 5 male Swiss mice
were given two subcutaneous injections 21 days apart,
with the initial injections (day 0) given at 5-6 weeks of
age. On day 49 the subjects were sacrificed.

20 Immunological activity of the subject GnRH-LKT
fusions was assayed by measuring anti-GnRH antibody
titres using a standard radioimmunoassay procedure at a
1:1000 serum dilution. Biological effect of the GnRH-LKT
fusions was quantified by standard radioimmunoassay of
25 serum testosterone levels with a sensitivity of 25 pg/ml,
and testicular tissue was weighed and histologically
examined. The results of this trial are summarized in
Table 2.

In the trial, all animal subjects injected with
30 GnRH:LKT antigens had readily detectable antibody levels;
however, the LKT 111::GnRH fusion (from plasmid pCB111)
showed superior immunogenicity as indicated by uniformity
of response and titre. Serum testosterone (produced by
the testicular Leydig cells) is secreted in a pulsatile
35 manner, and accordingly, low values and extreme

variability of serum levels are expected in normal animal subjects. Under the trial, the control group (receiving the 0.2 ml adjuvant vaccine injections) had normal serum testosterone levels, while both groups of treated
5 subjects had essentially undetectable serum testosterone.

Further under the trial, histological evaluation of testicular tissue revealed varying degrees of Leydig cell atrophy, reduced seminiferous tubule diameter and interruption of spermatogenesis in treated
10 subjects; however, testicular weight remained close to normal in treated animals—even in the presence of high anti-GnRH antibody titres—although there was clear evidence of testicular regression in 2 of 5 subjects receiving the LKT 111::4 copy GnRH fusions.

15 Accordingly, these results show that multiple copies of GnRH ligated to either LKT 352 or LKT 111 comprise potent immunogens; and further, it is indicated that vaccination with the subject fusion proteins triggers production of antibodies which are able to
20 neutralize endogenous GnRH in vivo, and that a concomitant in vivo biological effect is discernable in animal subjects receiving such vaccinations.

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Ani- mal	Group 1			Group 2			Group 3		
	Control			5 µg LKT 352::4 Copy GnRH			5 µg LKT 111::4 Copy GnRH		
	Anti- body Titre*	Testic- ular Wt.(mg)	Serum Testos- terone†	Anti- body Titre*	Testic- ular Wt.(mg)	Serum Testos- terone†	Anti- body Titre*	Testic- ular Wt.(mg)	Serum Testos- terone†
1	7.0	252	.04	73.0	282	.13	75.0	163	.00
2	4.0	327	.18	14.0	334	.10	59.0	296	.07
3	0.0	276	2.73	18.0	254	.03	54.0	260	.24
4	0.0	220	.36	55.0	222	.05	66.0	265	.03
5	1.0	232	1.44	61.0	226	.19	64.0	50	.00
Mean	2.4	261	.95	44	263	.10	64	206	.07
Std Error	1.4	19	.51	12	21	.03	4	45	.04

* % Binding of 125 -GnRH at a 1:1000 serum dilution
 † ng/ml

Table 2

Example 8

In Vivo Immunologic Activity of
LKT::GnRH Fusions in Porcine Subjects

To test the ability of fusion proteins

5 comprising multiple tandem repeats of GnRH (ligated to either LKT 352 or LKT 111) to elicit anti-GnRH immunological response in vivo in porcine subjects, the following vaccination trial was preformed. Cultures of *E. coli* containing plasmids pCB113, pCB111, pCB175 and
10 pCB114 (LKT 352::4 copy GnRH, LKT 111::4 copy GnRH, LKT 352::8 copy GnRH, and LKT 111::8 copy GnRH, respectively) were prepared as described above. Vaccines from each of the above cultures were formulated to contain the equivalent of 50 µg GnRH and were administered in VSA-3
15 adjuvant in a 2.0 ml volume. Four groups of 5 male and 5 female weanling pigs, 35 days old (at day 0), were injected at day 0 and reinjected at day 21 of the trial. Blood samples were collected at days 0, 21 and 35, with anti-GnRH antibody titres being measured at a final
20 dilution of 1:1000 using a standard radioimmunoassay procedure. The assay results are summarized in Table 3.

Under the trial, anti-GnRH antibodies could not be detected in any subjects prior to immunization, but were readily detected in most subjects by day 35 (one
25 subject in treatment group 4 died due to an infection unrelated to treatment). The results in this trial indicate that fusion proteins comprising multiple GnRH repeats ligated to either a LKT 352 or LKT 111 carrier polypeptide form useful immunogens in porcine subjects.
30 Based on the predicted molecular weights of the decapeptide GnRH (1,200), the LKT 111 polypeptide (52,000) and the LKT 352 polypeptide (100,000), the percentages of GnRH in the LKT-GnRH antigen fusions are as follows: 4.9% (LKT 352::4 copy GnRH); 8.5% (LKT 111::4
35 copy GnRH); 9.3% (LKT 352::8 copy GnRH) and 15.7% (LKT

111::8 copy GnRH). Accordingly, the practical result thus obtained indicates that by using LKT-GnRH fusions comprising the LKT 111 polypeptide carrier, the overall amount of antigen (LKT-GnRH) administered to the subject
5 may be halved (as compared to vaccination compositions using the LKT 352 carrier polypeptide system) to obtain an equivalent anti-GnRH response.

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Animal Number	Group 1	Group 2	Group 3	Group 4
	LKT 352::4 copy GnRH 50 µg	LKT 111::4 copy GnRH 50 µg	LKT 352::8 copy GnRH 50 µg	LKT 111:: 8 copy GnRH 50 µg
	day 35 1:1000 dilution	day 35 1:1000 dilution	day 35 1:1000 dilution	day 35 1:1000 dilution
1	♂ 47.7	♀ 46.0	♂ 68.3	♂ 51.0
2	♀ 50.3	♂ 71.6	♂ 65.1	♂ 31.7
3	♀ 66.0	♀ 21.4	♀ 50.7	♀ 35.7
4	♀ 70.2	♂ 46.2	♂ 4.7	♀ 65.9
5	♂ 17.3	♀ 48.9	♀ 38.3	♀
6	♂ 18.3	♂ 69.4	♀ 17.4	♂ 11.3
7	♀ 14.7	♂ 47.9	♀ 51.4	♀ 28.3
8	♂ 37.0	♀ 44.4	♂ 18.0	♂ 43.0
9	♂ 26.0	♂ 70.8	♂ 83.5	♀ 78.7
10	♀ 2.7	♀ 37.8	♀ 24.2	♂ 55.9
Mean	35.0	50.4	42.2	44.6
Standard Deviation	7.3	5.1	8.1	6.9
Responders	9/10	10/10	9/10	9/9

Table 3

Example 9

Prediction of T-cell Epitopes in the Recombinant
LKT 352 and LKT 111 Molecules

5 In order to predict potential T-cell epitopes
in the leukotoxin polypeptide sequences employed in the
LKT-GnRH chimeras of the present invention, the method
proposed by Margalit and co-workers (Margalit et al., *J.*
Immunol (1987) 138:2213) was performed on the amino acid
10 sequence corresponding to numbers 1 through 199 of the
LKT molecule as depicted in Table 4. Under the subject
method, the amino acid sequence of the leukotoxin
polypeptide sequence was compared to other sequences
known to induce a T-cell response and to patterns of
types of amino acids which are believed to be required
15 for a T-cell epitope. The results of the comparison are
depicted in Table 4.

As can be seen by the predictive results thus
obtained, there are several short sequences in the
leukotoxin peptide which are identified as potential T-
20 cell epitopes using the criteria suggested by Margalit et
al (supra). More particularly, 9 sequences were
identified as having a (Charged/Gly - Hydrophobic -
Hydrophobic - Polar/Gly) sequence (indicated as pattern
"1" in Table 4), and 3 sequences were identified as
25 having a (Charged/Gly - Hydrophobic - Hydrophobic -
Hydrophobic/Pro - Polar/Gly) sequence (indicated as
pattern "2" in Table 4). By coupling these data with the
in vivo anti-GnRH activity produced by both the LKT 352
and the LKT 111 carrier systems in Examples 7 and 8
30 above, it is indicated that critical T-cell epitopes are
retained in the shortened LKT 111 molecule, and that
those epitopes are likely contained within the N-terminal
portion of the LKT 352 and LKT 111 molecules.

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Table 4

LKT Sequence Patterns Corresponding
To Potential T-cell Epitopes

LKT Amino Acid Sequences Showing Pattern "1":

5	GTID	(aa's 27-30)
	GITG	(aa's 66-69)
	GVIS	(aa's 69-72)
	HVAN	(aa's 85-88)
	KIVE	(aa's 93-96)
10	DLAG	(aa's 152-155)
	KVLS	(aa's 162-165)
	DAFE	(aa's 171-174)
	KLVD	(aa's 183-186)
	GIID	(aa's 192-195)

LKT Amino Acid Sequence Showing Pattern "2":

15	RYLAN	(aa's 114-118)
	KFLLN	(aa's 124-128)
	KAYVD	(aa's 167-171)

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D. Industrial Applicability

The leukotoxin-GnRH chimeras of the present invention are of use in providing immunogens that, when administered to a vertebrate host, serve to immunize the host against endogenous GnRH, which in turn acts to inhibit the reproductive function or capability of the host.

Notwithstanding the specific uses exemplified in this specification, the novel chimeric molecules disclosed herein suggest a means for providing fusion proteins comprising more than one GnRH peptide sequence, occurring in either multiple or tandem repeats, which are fused to immunogenic epitopes supplied by the leukotoxin polypeptide portion of the molecule (and in some cases by spacer peptide sequences occurring between selected GnRH sequences). The subject chimeric proteins constructed under the present invention provide enhanced immunogenicity to the fused GnRH peptide sequences, allowing an immunized vertebrate host to mount an effective immune response toward endogenous GnRH; effecting an interruption in the synthesis and release of the two gonadotropic hormones, luteinizing hormone (LH) and follicle stimulating hormone (FSH) and rendering the host temporarily sterile. In this manner, the novel leukotoxin-GnRH constructs may be employed in immunosterilization vaccines to provide an alternative to invasive sterilization procedures currently practiced in domestic and farm animal husbandry.

Other contemplated uses of the instant fusion molecules include population control, for example the interruption of reproduction capabilities in wild rodent populations. In this regard, the LKT-GnRH fusion molecules may be used as an alternative to population control measures currently practiced, such as poisoning and the like. The fusion products of the instant

invention may also be administered in constructs having both slow and fast release components. In this manner, the need for multiple vaccinations may be avoided. Further, since the amino acid sequence of GnRH is highly conserved among species, a single leukotoxin-GnRH fusion vaccine product may be produced which will exhibit broad cross species effectiveness.

Thus, various chimeric proteins comprising leukotoxin fused to selected GnRH polypeptides have been disclosed. Although preferred embodiments of the subject invention have been described in some detail, it is understood that obvious variations can be made without departing from the spirit and the scope of the invention as defined by the appended claims.

15

Deposits of Strains Useful in Practicing the Invention

A deposit of biologically pure cultures of the following strains was made with the American Type Culture Collection (ATCC), 12301 Parklawn Drive, Rockville, Maryland. The accession number indicated was assigned after successful viability testing, and the requisite fees were paid. The deposits were made under the provisions of the Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purpose of Patent Procedure and the Regulations thereunder (Budapest Treaty). This assures maintenance of viable cultures for a period of thirty (30) years from the date of deposit and at least five (5) years after the most recent request for the furnishing of a sample of the deposit by the depository. The organisms will be made available by the ATCC under the terms of the Budapest Treaty, which assures permanent and unrestricted availability of the cultures to one determined by the U.S. Commissioner of Patents and Trademarks to be entitled thereto according to 35 USC §122 and the

Commissioner's rules pursuant thereto (including 37 CFR §1.12).

These deposits are provided merely as convenience to those of skill in the art, and are not an admission that a deposit is required under 35 USC §112. The nucleic acid sequences of these plasmids, as well as the amino acid sequences of the polypeptides encoded thereby, are incorporated herein by reference and are controlling in the event of any conflict with the description herein. A license may be required to make, use, or sell the deposited materials, and no such license is hereby granted.

<u>Strain</u>	<u>Deposit Date</u>	<u>ATCC No.</u>
P. haemolytica serotype 1 B122	February 1, 1989	53863
pAA352 in <i>E. coli</i> W1485	March 30, 1990	68283
pCB113 in <i>E. coli</i> JM105	February 1, 1995	69749
pCB111 in <i>E. coli</i> JM105	February 1, 1995	69748

Claims:

1. A chimeric protein comprising a leukotoxin polypeptide fused to a multimer consisting essentially of more than one selected GnRH polypeptide, whereby said leukotoxin portion of said chimeric protein acts to increase the immunogenicity of said GnRH multimer.
2. The chimeric protein of claim 1 wherein said leukotoxin polypeptide lacks leukotoxic activity.
3. The chimeric protein of claim 2 wherein said leukotoxin is LKT 352.
4. The chimeric protein of claim 2 wherein said leukotoxin is LKT 111.
5. The chimeric protein of claim 1 wherein said GnRH multimer comprises a molecule according to the general formula GnRH-X-GnRH wherein X is selected from the group consisting of a peptide linkage, an amino acid spacer group, a leukotoxin polypeptide and $[\text{GnRH}]_n$ where n is greater than or equal to 1, and further wherein GnRH comprises any GnRH polypeptide.
6. The chimeric protein of claim 5 wherein X comprises an amino acid spacer group including at least one helper T-cell epitope.
7. The chimeric protein of claim 1 wherein said chimeric protein comprises the amino acid sequence depicted in Figure 5, or an amino acid sequence substantially homologous and functionally equivalent thereto.

8. The chimeric protein of claim 1 wherein said chimeric protein comprises the amino acid sequence depicted in Figure 7, or an amino acid sequence substantially homologous and functionally equivalent thereto.

9. A vaccine composition comprising the chimeric protein of any of claims 1-8 and a pharmaceutically acceptable vehicle.

10. A method for presenting a selected GnRH multimer to a subject comprising administering to said subject an effective amount of a vaccine composition according to claim 9.

11. A DNA construct encoding the chimeric protein of any of claims 1-8.

12. An expression cassette comprised of:
(a) the DNA construct of claim 11; and
(b) control sequences that direct the transcription of said construct whereby said construct can be transcribed and translated in a host cell.

13. A host cell transformed with the expression cassette of claim 12.

14. A method of producing a recombinant polypeptide comprising:

(a) providing a population of host cells according to claim 13; and
(b) culturing said population of cells under conditions whereby the polypeptide encoded by said expression cassette is expressed.

Gln His Trp Ser Tyr Gly Leu Arg Pro Gly
 ...CAG CAT TGG AGC TAC GGC CTG CGC CCT GGC...
 ...GTC GTA ACC TCG ATG CCG GAC GCG GGA CCG...

GnRH-1:

FIG. 1A

(1) Gln His Trp Ser Tyr Gly Leu Arg Pro Gly Ser Gly Ser (2) Gln Asp Trp Ser
 ...CAG CAT TGG AGC TAC GGC CTG CGC CCT GGC AGC GGT TCT CAA GAT TGG AGC
 ...GTC GTA ACC TCG ATG CCG GAC GCG GGA CCG TCG CCA AGA GTT CTA ACC TCG
 1 5 10 15

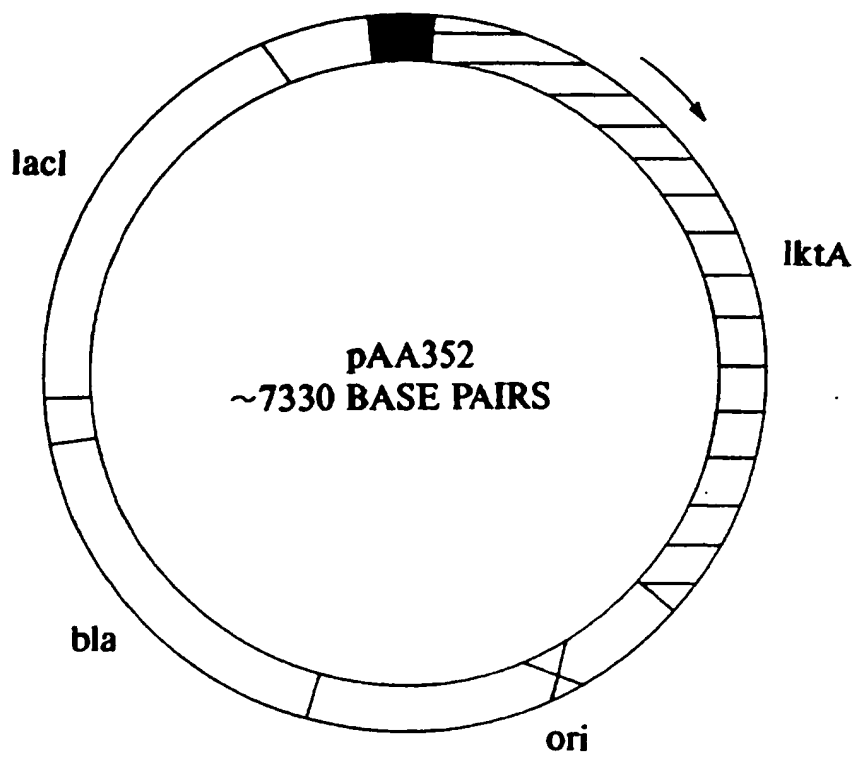
GnRH-2:

Tyr	Gly	Leu	Arg	Pro	Gly	Gly	Ser	Ser	Gln	His	Tyr	Ser	Tyr	Gly	Leu	Arg
ATAC	GGC	CTG	CGT	CCG	GGT	GGC	TCT	AGC	CAG	CAT	TGG	AGC	TAC	GGC	CTG	CGC
ATG	CCG	GCA	GCA	GGC	CCA	CCG	AGA	TCG	GTC	GTA	ACC	TCG	ATG	CCG	GAC	CGC
							25					30				
							20									

Pro	Gly	Ser	Gly	Ser	Gln	Asp	Trp	Ser	Tyr	Gly	Leu	Arg	Pro	Gly
CCT	GGC	AGC	AGC	AGC	CAA	GAT	TGG	AGC	TAC	GGC	CTG	CGT	CCG	GGT...
GGG	CCG	TCG	CCA	TCG	GTT	CTA	ACC	TCG	ATG	CCG	GAC	GCA	GGC	CCA...
35					40					45				49

FIG. 1B

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**FIG. 2**

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10	20	30	40	50	60	70	80	90
ATG GCT ACT GGT ATA GAT CTA AGC TTC CCA AAA ACT GGG GCA AAA AAA ATT ATC CTC TAT ATT CCC CAA AAT TAC CAA TAT GAT ACT GAA	TAC CGA TGA CAA TAT CTA GAT TCG AAG GGT TTT TGA CCC CGT TTT TTT TTT TAA TAG GAG ATA TAA GGG GTT TTA ATG GTT ATA CTA TGA CTT	Met Ala Thr Val Ile Asp Leu Ser Phe Pro Lys Thr Gly Ala LYS LYS Ile Ile Leu Tyr Ile Pro Gln Asn Tyr Gln Tyr Asp Thr Glu	RECOMBINANT	LEUKOTOXIN PEPTIDE	RECOMBINANT	RECOMBINANT	RECOMBINANT	RECOMBINANT
a	a	a	a	a	a	a	a	a
100	110	120	130	140	150	160	170	180
CAA GGT AAT GGT TTA CAG GAT TTA GTC AAA GCG GCC GAA GAG TTG GGG ATT GAG GTA CAA AGA GAA GAA CGC AAT AAT ATT GCA ACA GCT	GGT CCA TTA CCA AAT GTC CTA AAT CAG TTT CGC CGG CTT CTC AAC CCC TAA CTC CAT GTT TCT CTT CTT GCG TTA TTA TAA CGT TGT CGA	Gln Gly Asn Gly Leu Gln Asp Leu Val Lys Ala Ala Gly Glu Leu Gly Ile Glu Val Gln Arg Glu Arg Asn Asn Ile Ala Thr Ala	RECOMBINANT	LEUKOTOXIN PEPTIDE	RECOMBINANT	RECOMBINANT	RECOMBINANT	RECOMBINANT
c	c	c	c	c	c	c	c	c
190	200	210	220	230	240	250	260	270
CAA ACC AGT TTA GGC ACG ATT CAA ACC GCT ATT GGC TTA ACT GAG CGT GGC ATT GTG TTA TCC GCT CCA CAA ATT GAT AAA TTG CTA CAG	GTT TGG TCA AAT CCG TGC TAA GAT TGG CGA TAA CCG AAT TGA CTC GCA CCG TAA CAC AAT AAG CGA GGT GTT TAA CTA TTT AAC GAT GTC	Gln Thr Ser Leu Gly Thr Ile Gln Thr Ala Ile Gly Leu Thr Glu Arg Gly Ile Val Leu Ser Ala Pro Gln Ile Asp Lys Leu Glu	RECOMBINANT	LEUKOTOXIN PEPTIDE	RECOMBINANT	RECOMBINANT	RECOMBINANT	RECOMBINANT
c	c	c	c	c	c	c	c	c

FIG. 3A

280	290	300	310	320	330	340	350	360
AAA ACT AAA GCA GGC CAA GCA TTA GGT TCT GCC GAA AGC ATT GTA CAA AAT GCA AAT AAA GCC AAA ACT GTA TTA TCT GGC ATT CAA TCT	TTT TGA TTT CGT CCG GTT CAT GGT TTA CCA AGA CCG CTT TCG TAA CAT GGT TTA CCG TTT TGA CAT AAT AGA CCG TAA GTT AGA	Lys Thr Lys Ala Gly Gln Ala Leu Gly Ser Ala Gln Ser Ile Val Gln Asn Ala Asp Lys Thr Val Leu Ser Gly Ile Gln Ser	RECOMBINANT LEUKOTOXIN PEPTIDE					
370	380	390	400	410	420	430	440	450
ATT TTA GGC TCA GTA TTG GCT GGA ATG GAT TTA GAT GAG GCC TTA CAG AAT AAC AGC AAC CAA CAT GCT CTT GCT AAA GCT GGC TTG GAG	TAA AAT CCG AGT CAT AAC CGA CCT TAC CTA AAT CTA CTC CGG AAT GTC TTA TTG TCG TCG GTT GTA CGA GAA CGA TTT CGA CCG AAC CTC	Ile leu Gly Ser Val Leu Ala Gly Met Asp Leu Asp Glu Ala Leu Gln Asn Asn Ser Asn Gln His Ala Leu Ala Lys Ala Gly Leu Glu	RECOMBINANT LEUKOTOXIN PEPTIDE					
460	470	480	490	500	510	520	530	540
CTA ACA AAT TCA TTA ATT GAA AAT ATT GCT AAT TCA GTA AAA ACA CTT GAC GAA TTT GGT GAG CAA ATT AGT CAA TTT GGT TCA AAA CTA	GAT TGT TTA AGT AAT TAA CTT TTA TAA CGA TTA AGT CAT TTT TGT GAA CTG CTT AAA CCA CTC GGT TAA TCA GGT AAA CCA AGT TTT GAT	Leu Thr Asn Ser Leu Ile Glu Asn Ile Ala Asn Ser Val Lys Thr Leu Asp Glu Phe Gly Glu Gln Ile Ser Gln Phe Gly Ser Lys Leu	RECOMBINANT LEUKOTOXIN PEPTIDE					
550	560	570	580	590	600	610	620	630
CAA AAT ATC AAA GGC TTA GGG ACT TTA GGA GAC AAA CTC AAA AAT ATC GGT GGA CTT GAT AAA GCT GGC CTT GGT TTA GAT GTT ATC TCA	GTT TTA TAG TTT CCG AAT CCC AAT CCT CCA TTA GAG TTT TTA TAG CCA CCT GAA CTA TTT CGA CCG GAA CCA AAT CTA CAA TAG AGT	Gln Asn Ile Lys Gly Leu Gly Thr Leu Gly Asp Lys Leu Lys Lys Leu Lys Leu Asp Val Ile Ser	RECOMBINANT LEUKOTOXIN PEPTIDE					

FIG. 3B

[illegible]

SUBSTITUTE SHEET (RULE 26)

FIG. 3C

910	920	930	940	950	960	970	980	990
GAG AGT TAT GCC GAA CGC TTT AAA TTA GGC TAT GAC GGA GAT AAT TTA TTA GCA GAA TAT CAG CGG GGA ACA GGG ACT ATT GAT GCA	CCT CTA ATA CGG CTT GCG AAA TTT TTT AAT CCG ATA CCG CCA CTA TTA AAT AAT CCG CCA TGT CCC TGA TAA CTA CGT	GIU Ser Tyr Ala Glu Arg Phe Lys Lys Leu Gly Tyr Asp Gly RECOMBINANT LEUKOTOXIN PEPTIDE						
1000	1010	1020	1030	1040	1050	1060	1070	1080
TCG GTT ACT GCA ATT AAT ACC GCA TTG GCC GCT ATT GCT GGT GGT GTG TCT GCT GCT GCA GGC GGC TCG GTT ATT GCT TCA CCG ATT GCC	AGC CAA TGA CGT TAA TTA TGG CGT AAC CGG CGA TAA CGA CGA CCA CAC AGA CGA CGA CGT CCG CGG AGC CAA TAA CGA AGT GGC TAA CGG	Ser Val Thr Ala Ile Asn Thr Ala Leu Ala Gly Ile Ala Gly RECOMBINANT LEUKOTOXIN PEPTIDE						
1090	1100	1110	1120	1130	1140	1150	1160	1170
TTA TTA GTA TCT GGG ATT ACC GGT GTA ATT TCT ACG ATT CTG CAA TAT TCT AAA TTT GGT AAA TTT GAG CAC GGT GCA AAT AAA ATT CAT	AAT AAT CAT AGA CCC TAA TGG CCA CAT TAA AGA TGC TAA GAC GTT ATA AGA TTT GGT TAC AAA CTC GTG CAA CGT TTA TTT TAA GTA	Leu Leu Val Ser Gly Ile Thr Gly Val Ile Ser Thr Ile Leu RECOMBINANT LEUKOTOXIN PEPTIDE						
1180	1190	1200	1210	1220	1230	1240	1250	1260
AAC AAA ATT GTA GAA TGG GAA AAA AAT AAT CAC GGT AAG AAC TAC TTT GAA AAT GGT TAC GAT GCC CGT TAT CTT GCG AAT TTA CAA GAT	TTG TTT TAA CAT CTT ACC CTT TTT TTA TTA GTG CCA TTC TTG CCA TTC TTG ATG AAA CTT TTA CCA ATG CTA CGG GCA ATA GAA CGC TTA AAT GTT CTA	Asn Lys Ile Val Glu Trp Glu Lys Asn Asn His Gly Lys Asn Tyr Phe Glu Asn Gly Tyr Asp Ala Arg Tyr Leu Ala Asn Leu Gln ASD						

FIG. 3D

1270	1280	1290	1300	1310	1320	1330	1340	1350
ATG AAA TTC TTA CTG AAC TTA AAC AAA GAG TTA CAG GCA GAA CGT GTC ATC GCT ATT ACT CAG CAG CAA TGG GAT AAC ATT GGT	TTA TAC TTT AAG AAT TTG TTT CTC AAT AAT GTC CGT CTT GCA CAG TAG CGA TAA TGA GTC GTC GGT ACC CTA TTG TTG TAA CCA	Asn Met Lys Phe Leu Leu Asn Leu Asn Lys Glu Leu Gln Ala	RECOMBINANT	LEUKOTOXIN PEPTIDE	Leu Gln Ala Ile Thr Gln Gln Thr Gln Gln Thr Gln Gln Thr Gln Gln Thr Gln Gln Thr Gln Gln Thr Gln Gln Thr	Asn Ile Gly		
1360	1370	1380	1390	1400	1410	1420	1430	1440
GAT TTA GCT GGT ATT AGC CGT TTA GGT GAA AAA GTC CTT AGT GGT AAA GCC TAT GTG GAT GCG TTT GAA GAA GGC AAA CAC ATT AAA GCC	CTA AAT CGA CCA TAA TCG GCA AAT CCA CTT TTT CAG GAA TCA CCA TTT CGG ATA CAC CTA CGC AAA CTT CTT CCG TTT GTG TAA TTT CGG	Asp Leu Ala Gly Ile Ser Arg Leu Gly Glu Lys Val Leu Ser	RECOMBINANT	LEUKOTOXIN PEPTIDE	Gly Val Asp Ala Phe Glu Glu Gly Lys His			
1450	1460	1470	1480	1490	1500	1510	1520	1530
GAT AAA TTA GTA CAG TTG GAT TCG GCA AAC GGT ATT ATT GAT GTG AGT AAT TCG GGT AAA GCG AAA ACT CAG CAT ATC TTA TTC AGA ACG	CTA TTT AAT CAT GTC AAC CTA AGC CGT TTG CCA TAA TAA CTA TTA AGC CCA TTT TTT CGC TTT TGA GTC GTA TAG AAT AAG TCT TGC	Asp Lys Leu Val Gln Leu Asp Ser Ala Asn Gly Ile Ile Asp	RECOMBINANT	LEUKOTOXIN PEPTIDE	Lys Thr Gln His Ile Leu Phe Arg Thr			

SUBSTITUTE SHEET (RULE 26)

FIG. 3E

[illegible]

FIG. 3F

1900	1910	1920	1930	1940	1950	1960	1970	1980
AGT TAT ACC GTA AAT CGT TTC GTA GAA ACC GGT AAA GCA CTA CAC GAA GTG ACT TCA ACC CAT ACC GCA TTA GTG GGC AAC CGT GAA GAA	TCA ATA TGG CAT TTA GCA AAG CAT CTT TGG CCA TTT CGT GAT GTG CTT CAC TGA AGT TGG GTA TGG CGT AAT CAC CCG TTG GCA CTT CTT	Ser Tyr Thr Val Asn Arg Phe Val Glu Thr Gly Lys Ala Leu His Glu Val Thr Ser Thr His Thr Ala Leu Val Gly Asn Arg Glu Glu	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE
1990	2000	2010	2020	2030	2040	2050	2060	2070
AAA ATA GAA TAT CGT CAT AGC AAT AAC CAG CAC CAT GCC GGT TAT TAC ACC AAA GAT ACC TTG AAA GCT GTT GAA GAA ATT ATC GGT ACA	TTT TAT ATA GCA GTA TCG TTA TTG GTC GTG GTA CGG CCA ATA ATG TGG TTT CTA TGG AAC TTT CGA CAA CTT CTT TAA TAG CCA TGT	Lys Ile Glu Tyr Arg His Ser Asn Asn Gln His His Ala Gly Tyr Tyr Thr Lys Asp Thr Leu Lys Ala Val Glu Glu Ile Ile Gly Thr	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE
2080	2090	2100	2110	2120	2130	2140	2150	2160
TCA CAT AAC GAT ATC TTT AAA GGT AGT AAG TTC AAT GAT GCC TTT AAC GGT GGT GAT GAT GTC GAT ACT ATT GAC GGT AAC GAC GGC AAT	AGT GTA TTG CTA TAG AAA TTT CCA TCA TTC AAG TTA CTA CGG AAA TTG CCA CCA CTA CCA CCA CTA CCA CAG CTA TGA TAA CTT GGT CCA TTG CTG CCG TTA	Ser His Asn Asp Ile Phe Lys Gly Ser Lys Phe Asn Asp Ala Phe Asn Gly Gly Asp Gly Val Asp Thr Ile Asp Gly Asn Asp Gly Asn	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE	RECOMBINANT LEUKOTOXIN PEPTIDE

FIG. 3G

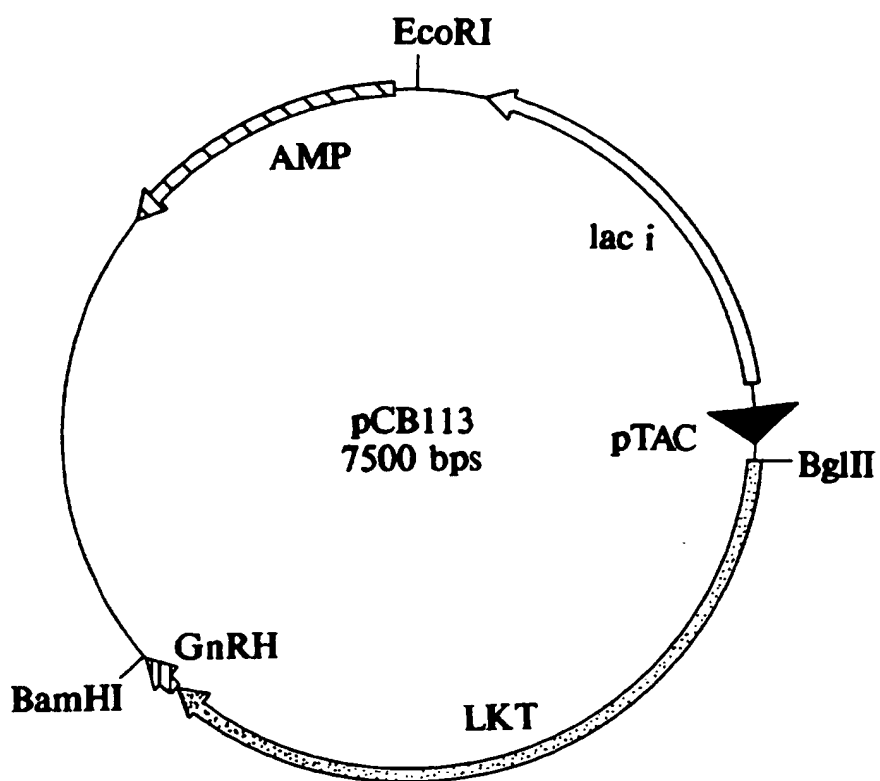
2170	2180	2190	2200	2210	2220	2230	2240	2250
•	•	•	•	•	•	•	•	•
GAC CGC TTA TTT GGT GGT AAA GGC GAT ATT CTC GAT GGT AAT GGA AAT GGT GAT TTT ATC GAT GGC GGT AAA GGC AAC GAC CTA TTA	CTG GCG AAT AAA CCA CCA TTT CCG CTA CTA TAA GAG CTA CCA CCT TTA CCA CCA CTA CTA AAA TAG CTA CCG CCA TTT CCG TTG CTG GAT AAT	CTG Arg Leu Phe Gly Lys Gly Asp Ile	RECOMBINANT	LEUKOTOXIN PEPTIDE	•	•	•	•
2260	2270	2280	2290	2300	2310	2320	2330	2340
•	•	•	•	•	•	•	•	•
CAC GGT GGC AAG GGC GAT GAT ATT TTC GTT CAC CGT AAA GGC GAT GGT AAT GAT ATT ACC GAT TCT GAC GGC AAT GAT AAA TTA TCA	CTG CCA CCG TTC CCG CTA CTA TAA AAG CAA GTG GCA TTT CCG CTA CCA TTA CTA TAA TAA TGG CTA AGA CTG CCG TTA CTA TTT AAT AGT	His Gly Lys Lys Gly Asp Ile Phe Val His	RECOMBINANT	LEUKOTOXIN PEPTIDE	•	•	•	•
2350	2360	2370	2380	2390	2400	2410	2420	2430
•	•	•	•	•	•	•	•	•
TTC TCT GAT TCG AAC TTA AAA GAT TTA ACA GAT TTA ACA TTT GAA AAA GTT AAA CAT AAT CTT GTC ATC ACG AAT AGC AAA AAA GAG AAA GTG ACC ATT	AAG AGA CTA AGC TTG AAT TTT CTA AAT TGT AAA CTT TTT CAA TTT GTA TTA GAA CAG TAG TGC TTA TCG TTT TTT CTT CTT CAC TGG TAA	Phe Ser Asp Ser Asn Leu Lys Asp Leu Thr Phe	RECOMBINANT	LEUKOTOXIN PEPTIDE	•	•	•	•
2440	2450	2460	2470	2480	2490	2500	2510	2520
•	•	•	•	•	•	•	•	•
CAA AAC TGG TTC CGA GAG GCT GAT TTT GCT AAA GAA GTG CCT AAT TAT AAA GCA ACT AAA GAT GAG AAA ATC GAA GAA ATC ATC GGT CAA	GTT TTG ACC AAG GCT CTC CGA CTA AAA CGA TTT CTT CAC GGA TTA ATA TTT CCG TGA TTT TTA TTA TTT TAG CTT CTT TAG TAG CCA GTT	Gln Asn Trp Phe Arg Glu Ala Asp Phe Ala Lys	RECOMBINANT	LEUKOTOXIN PEPTIDE	•	•	•	•

FIG. 3H

[illegible]

FIG. 31

12 / 25

**FIG. 4**

13/25

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      10      20      30      40
      |      |      |      |
ATG GCT ACT GTT ATA GAT CTA AGC TTC CCA AAA ACT GGG GCA AAA
MET Ala Thr Val Ile Asp Leu Ser Phe Pro Lys Thr Gly Ala Lys

      50      60      70      80      90
      |      |      |      |      |
AAA ATT ATC CTC TAT ATT CCC CAA AAT TAC CAA TAT GAT ACT GAA
Lys Ile Ile Leu Tyr Ile Pro Gln Asn Tyr Gln Tyr Asp Thr Glu

     100     110     120     130
     |     |     |     |
CAA GGT AAT GGT TTA CAG GAT TTA GTC AAA GCG GCC GAA GAG TTG
Gln Gly Asn Gly Leu Gln Asp Leu Val Lys Ala Ala Glu Glu Leu

     140     150     160     170     180
     |     |     |     |     |
GGG ATT GAG GTA CAA AGA GAA GAA CGC AAT AAT ATT GCA ACA GCT
Gly Ile Glu Val Gln Arg Glu Glu Arg Asn Asn Ile Ala Thr Ala

     190     200     210     220
     |     |     |     |
CAA ACC AGT TTA GGC ACG ATT CAA ACC GCT ATT GGC TTA ACT GAG
Gln Thr Ser Leu Gly Thr Ile Gln Thr Ala Ile Gly Leu Thr Glu

     230     240     250     260     270
     |     |     |     |     |
CGT GGC ATT GTG TTA TCC GCT CCA CAA ATT GAT AAA TTG CTA CAG
Arg Gly Ile Val Leu Ser Ala Pro Gln Ile Asp Lys Leu Leu Gln

     280     290     300     310

AAA ACT AAA GCA GGC CAA GCA TTA GGT TCT GCC GAA AGC ATT GTA
Lys Thr Lys Ala Gly Gln Ala Leu Gly Ser Ala Glu Ser Ile Val

     320     330     340     350     360
     |     |     |     |     |
CAA AAT GCA AAT AAA GCC AAA ACT GTA TTA TCT GGC ATT CAA TCT
Gln Asn Ala Asn Lys Ala Lys Thr Val Leu Ser Gly Ile Gln Ser

     370     380     390     400
     |     |     |     |
ATT TTA GGC TCA GTA TTG GCT GGA ATG GAT TTA GAT GAG GCC TTA
Ile Leu Gly Ser Val Leu Ala Gly MET Asp Leu Asp Glu Ala Leu

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FIG. 5A

SUBSTITUTE SHEET (RULE 26)

14 / 25

410	420	430	440	450
CAG	AAT	AAC	AGC	AAC
Gln	Asn	Asn	Ser	Asn
420	CAA	CAT	GCT	CTT
Gln	His	Ala	Leu	Ala
430	GCT	AAA	GCT	GGC
Leu	Lys	Ala	Gly	Leu
440	TTG	GAG		
GAG				
460	470	480	490	
CTA	ACA	AAT	TCA	TTA
Leu	Thr	Asn	Ser	Leu
470	ATT	GAA	AAT	ATT
Ile	Glu	Asn	Ile	Ala
480	GCT	AAT	TCA	GTA
Ala	Asn	Ser	Val	Lys
490	AAA	ACA		
ACA				
500	510	520	530	540
CTT	GAC	GAA	TTT	GGT
Leu	Asp	Glu	Phe	Gly
510	GGT	GAG	CAA	ATT
Glu	Gln	Ile	Ser	Gln
520	AGT	CAA	TTT	GGT
Ile	Ser	Gln	Phe	Gly
530	TCA	AAA	CTA	
Ser	Lys	Leu		
540				
550	560	570	580	
CAA	AAT	ATC	AAA	GGC
Gln	Asn	Ile	Lys	Gly
560	TTA	GGG	ACT	TTA
Lys	Gly	Leu	Gly	Thr
570	GGA	GAC	AAA	CTC
Leu	Gly	Asp	Lys	Leu
580	AAA	AAT		
Leu	Lys	Asn		
590	600	610	620	630
ATC	GGT	GGA	CTT	GAT
Ile	Gly	Gly	Leu	Asp
600	GAT	AAA	GCT	GGC
Asp	Lys	Ala	Gly	Leu
610	CTT	GGT	TTA	GAT
Leu	Gly	Leu	Asp	Val
620	GTT	ATC	TCA	
Val	Ile	Ser		
630				
640	650	660	670	
GGG	CTA	TTA	TCG	GGC
Gly	Leu	Leu	Ser	Gly
650	GCA	ACA	CCT	GCA
Ala	Thr	Ala	Ala	Leu
660	CTT	GTA	CTT	GCA
Leu	Val	Leu	Ala	Asp
670	GAT	AAA		
Asp	Lys			
680	690	700	710	720
AAT	GCT	TCA	ACA	GCT
Asn	Ala	Ser	Thr	Ala
690	AAA	AAA	GTG	GGT
Lys	Lys	Val	Gly	Ala
700	GGT	GCG	GGT	TTT
Ala	Gly	Phe	Glu	Leu
710	GAA	TTG	GCA	
Leu	Ala			
720				
730	740	750	760	
AAC	CAA	GTT	GTT	GGT
Asn	Gln	Val	Val	Gly
740	AAT	ATT	ACC	AAA
Asn	Ile	Thr	Lys	Ala
750	GCC	GTT	TCT	TCT
Ala	Val	Ser	Ser	Tyr
760	TAC	ATT		
Ile				
770	780	790	800	810
TTA	GCC	CAA	CGT	GTT
Leu	Ala	Gln	Arg	Val
780	GCA	GCA	GGT	TTA
Ala	Ala	Gly	Leu	Ser
790	TCT	TCA	ACT	GGG
Ser	Ser	Thr	Gly	Pro
800	GGG	CCT	GTG	
Val				
810				

FIG. 5B

15/25

	820		830		840		850							
GCT	GCT	TTA	ATT	GCT	TCT	ACT	GTT	TCT	CTT	GCG	ATT	AGC	CCA	TTA
Ala	Ala	Leu	Ile	Ala	Ser	Thr	Val	Ser	Leu	Ala	Ile	Ser	Pro	Leu

	860		870		880		890		900					
GCA	TTT	GCC	GGT	ATT	GCC	GAT	AAA	TTT	AAT	CAT	GCA	AAA	AGT	TTA
Ala	Phe	Ala	Gly	Ile	Ala	Asp	Lys	Phe	Asn	His	Ala	Lys	Ser	Leu

	910		920		930		940							
GAG	AGT	TAT	GCC	GAA	CGC	TTT	AAA	AAA	TTA	GCC	TAT	GAC	GGA	GAT
Glu	Ser	Tyr	Ala	Glu	Arg	Phe	Lys	Lys	Leu	Gly	Tyr	Asp	Gly	Asp

	950		960		970		980		990					
AAT	TTA	TTA	GCA	GAA	TAT	CAG	CGG	GGA	ACA	GGG	ACT	ATT	GAT	GCA
Asn	Leu	Leu	Ala	Glu	Tyr	Gln	Arg	Gly	Thr	Gly	Thr	Ile	Asp	Ala

	1000		1010		1020		1030							
TCG	GTT	ACT	GCA	ATT	AAT	ACC	GCA	TTG	GCC	GCT	ATT	GCT	GGT	GGT
Ser	Val	Thr	Ala	Ile	Asn	Thr	Ala	Leu	Ala	Ala	Ile	Ala	Gly	Gly

	1040		1050		1060		1070		1080					
GTG	TCT	GCT	GCT	GCA	GCC	GGC	TCG	GTT	ATT	GCT	TCA	CCG	ATT	GCC
Val	Ser	Ala	Ala	Ala	Ala	Gly	Ser	Val	Ile	Ala	Ser	Pro	Ile	Ala

	1090		1100		1110		1120							
TTA	TTA	GTA	TCT	GGG	ATT	ACC	GGT	GTA	ATT	TCT	ACG	ATT	CTG	CAA
Leu	Leu	Val	Ser	Gly	Ile	Thr	Gly	Val	Ile	Ser	Thr	Ile	Leu	Gln

	1130		1140		1150		1160		1170					
TAT	TCT	AAA	CAA	GCA	ATG	TTT	GAG	CAC	GTT	GCA	AAT	AAA	ATT	CAT
Tyr	Ser	Lys	Gln	Ala	<u>MET</u>	Phe	Glu	His	Val	Ala	Asn	Lys	Ile	His

	1180		1190		1200		1210							
AAC	AAA	ATT	GTA	GAA	TGG	GAA	AAA	AAT	AAT	CAC	GGT	AAG	AAC	TAC
Asn	Lys	Ile	Val	Glu	Trp	Glu	Lys	Asn	Asn	His	Gly	Lys	Asn	Tyr

FIG. 5C
SUBSTITUTE SHEET (RULE 26)

16 / 25

1220	1230	1240	1250	1260
TTT	GAA	AAT	GGT	TAC
Phe	Glu	Asn	Gly	Tyr
1270	1280	1290	1300	
AAT	ATG	AAA	TTC	TTA
Asn	<u>MET</u>	Lys	Phe	Leu
1310	1320	1330	1340	1350
CGT	GTC	ATC	GCT	ATT
Arg	Val	Ile	Ala	Ile
1360	1370	1380	1390	
GAT	TTA	GCT	GGT	ATT
Asp	Leu	Ala	Gly	Ile
1400	1410	1420	1430	1440
AAA	GCC	TAT	GTG	GAT
Lys	Ala	Tyr	Val	Asp
1450	1460	1470	1480	
GAT	AAA	TTA	GTA	CAG
Asp	Lys	Leu	Val	Gln
1490	1500	1510	1520	1530
AGT	AAT	TCG	GGT	AAA
Ser	Asn	Ser	Gly	Lys
1540	1550	1560	1570	
CCA	TTA	TTG	ACG	CCG
Pro	Leu	Leu	Thr	Pro
1580	1590	1600	1610	1620
GGT	AAA	TAT	GAA	TAT
Gly	Lys	Tyr	Glu	Tyr

FIG. 5D

17/25

1630	1640	1650	1660	
AGC	TGG	AAA	ATT	ACA
Ser	Trp	Lys	Ile	Thr
GAT	GGT	GCA	GCA	AGT
Asp	Gly	Ala	Ala	Ser
TCT	ACC	TTT	GAT	TTA
Thr	Phe	Asp	Leu	

1670	1680	1690	1700	1710
ACT	AAC	GTT	GTT	CAG
Thr	Asn	Val	Val	Gln
CGT	ATT	GGT	ATT	GAA
Arg	Ile	Gly	Ile	Glu
TTA	GAC	AAT	GCT	GGA
Leu	Asp	Asn	Ala	Gly

1720	1730	1740	1750	
AAT	GTA	ACT	AAA	ACC
Asn	Val	Thr	Lys	Thr
AAA	GAA	ACA	AAA	ATT
Lys	Glu	Thr	Lys	Ile
ATT	GCC	AAA	CTT	GGT
Ile	Ala	Lys	Leu	Gly

1760	1770	1780	1790	1800
GAA	GGT	GAT	GAC	AAC
Glu	Gly	Asp	Asp	Asn
GTA	TTT	GTT	GGT	TCT
Val	Phe	Val	Gly	Ser
ACG	ACG	GAA	ATT	
Thr	Thr	Glu	Ile	

1810	1820	1830	1840	
GAT	GGC	GGT	GAA	GGT
Asp	Gly	Gly	Glu	Gly
TAC	GAC	CGA	GTT	CAC
Tyr	Asp	Arg	Val	His
TAT	AGC	CGT	GGA	AAC
Ser	Arg	Gly	Asn	

1850	1860	1870	1880	1890
TAT	GGT	GCT	TTA	ACT
Tyr	Gly	Ala	Leu	Thr
ATT	GAT	GCA	ACC	AAA
Ile	Asp	Ala	Thr	Lys
GAG	ACC	GAG	CAA	GGT
Glu	Thr	Glu	Gln	Gly

1900	1910	1920	1930	
AGT	TAT	ACC	GTA	AAT
Ser	Tyr	Thr	Val	Asn
CGT	TTC	GTA	GAA	ACC
Arg	Phe	Val	Glu	Thr
GGT	AAA	GCA	CTA	CAC
Gly	Lys	Ala	Leu	His

1940	1950	1960	1970	1980
GAA	GTG	ACT	TCA	ACC
Glu	Val	Thr	Ser	Thr
CAT	ACC	GCA	TTA	GTG
His	Thr	Ala	Leu	Val
GGC	AAC	CGT	GAA	GAA
Gly	Asn	Arg	Glu	Glu

1990	2000	2010	2020	
AAA	ATA	GAA	TAT	CGT
Lys	Ile	Glu	Tyr	Arg
CAT	AGC	AAT	AAC	CAG
His	Ser	Asn	Asn	Gln
CAC	CAT	GCC	GGT	TAT
His	His	Ala	Gly	Tyr

FIG. 5E

18/25

2030	2040	2050	2060	2070
TAC ACC AAA GAT ACC	TTG AAA GCT GTT	GAA GAA ATT ATC	GGT ACA	
Tyr Thr Lys Asp Thr	Leu Lys Ala Val Glu Glu	Ile Ile Gly Thr		
2080	2090	2100	2110	
TCA CAT AAC GAT ATC	TTT AAA GGT AGT AAG	TTC AAT GAT GCC	TTT	
Ser His Asn Asp Ile	Phe Lys Gly Ser Lys	Phe Asn Asp Ala	Phe	
2120	2130	2140	2150	2160
AAC GGT GGT GAT GGT	GTC GAT ACT ATT	GAC GGT AAC GAC	GGC AAT	
Asn Gly Gly Asp Gly	Val Asp Thr Ile Asp	Gly Asn Asp Gly	Asn	
2170	2180	2190	2200	
GAC CGC TTA TTT GGT	GGT AAA GGC GAT GAT	ATT CTC GAT GGT	GGA	
Asp Arg Leu Phe Gly	Gly Lys Gly Asp Asp	Ile Leu Asp Gly	Gly	
2210	2220	2230	2240	2250
AAT GGT GAT GAT TTT	ATC GAT GGC GGT	AAA GGC AAC GAC	CTA TTA	
Asn Gly Asp Asp Phe	Ile Asp Gly Gly Lys	Gly Asn Asp Leu	Leu	
2260	2270	2280	2290	
CAC GGT GGC AAG GGC	GAT GAT ATT TTC	GTT CAC CGT AAA	GGC GAT	
His Gly Gly Lys Gly	Asp Asp Ile Phe Val	His Arg Lys Gly	Asp	
2300	2310	2320	2330	2340
GGT AAT GAT ATT ATT	ACC GAT TCT GAC	GGC AAT GAT AAA	TTA TCA	
Gly Asn Asp Ile Ile	Thr Asp Ser Asp Gly	Asn Asp Lys Leu	Ser	
2350	2360	2370	2380	
TTC TCT GAT TCG AAC	TTA AAA GAT TTA	ACA TTT GAA AAA	GTT AAA	
Phe Ser Asp Ser Asn	Leu Lys Asp Leu Thr	Phe Glu Lys Val	Lys	
2390	2400	2410	2420	2430
CAT AAT CTT GTC ATC	ACG AAT AGC AAA	AAA GAG AAA GTG	ACC ATT	
His Asn Leu Val Ile	Thr Asn Ser Lys Lys	Glu Lys Val Thr	Ile	

FIG. 5F

SUBSTITUTE SHEET (RULE 26)

19/25

2440	2450	2460	2470	
CAA AAC TGG TTC CGA GAG GCT GAT TTT GCT AAA GAA GTG CCT AAT				
Gln Asn Trp Phe Arg Glu Ala Asp Phe Ala Lys Glu Val Pro Asn				
2480	2490	2500	2510	2520
TAT AAA GCA ACT AAA GAT GAG AAA ATC GAA GAA ATC ATC GGT CAA				
Tyr Lys Ala Thr Lys Asp Glu Lys Ile Glu Glu Ile Ile Gly Gln				
2530	2540	2550	2560	
AAT GGC GAG CGG ATC ACC TCA AAG CAA GTT GAT GAT CTT ATC GCA				
Asn Gly Glu Arg Ile Thr Ser Lys Gln Val Asp Asp Leu Ile Ala				
2570	2580	2590	2600	2610
AAA GGT AAC GGC AAA ATT ACC CAA GAT GAG CTA TCA AAA GTT GTT				
Lys Gly Asn Gly Lys Ile Thr Gln Asp Glu Leu Ser Lys Val Val				
2620	2630	2640	2650	
GAT AAC TAT GAA TTG CTC AAA CAT AGC AAA AAT GTG ACA AAC AGC				
Asp Asn Tyr Glu Leu Leu Lys His Ser Lys Asn Val Thr Asn Ser				
2660	2670	2680	2690	2700
TTA GAT AAG TTA ATC TCA TCT GTA AGT GCA TTT ACC TCG TCT AAT				
Leu Asp Lys Leu Ile Ser Ser Val Ser Ala Phe Thr Ser Ser Asn				
2710	2720	2730	2740	
GAT TCG AGA AAT GTA TTA GTG GCT CCA ACT TCA ATG TTG GAT CAA				
Asp Ser Arg Asn Val Leu Val Ala Pro Thr Ser <u>MET</u> Leu Asp Gln				
2750	2760	2770	2780	2790
AGT TTA TCT TCT CTT CAA TTT GCT AGG GGA TCT CAG CAT TGG AGC				
Ser Leu Ser Ser Leu Gln Phe Ala Arg Gly Ser Gln His Trp Ser				
2800	2810	2820	2830	
TAC GGC CTG CGC CCT GGC AGC GGT TCT CAA GAT TGG AGC TAC GGC				
Tyr Gly Leu Arg Pro Gly Ser Gly Ser Gln Asp Trp Ser Tyr Gly				

FIG. 5G
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20/25

2840 2850 2860 2870 2880
 CTG CGT CCG GGT GGC TCT ACC CAG CAT TGG AGC TAC GGC CTG CGC
 Leu Arg Pro Gly Gly Ser Ser Gln His Trp Ser Tyr Gly Leu Arg

2890 2900 2910 2920
 CCT GGC AGC GGT AGC CAA GAT TGG AGC TAC GGC CTG CGT CCG GGT
 Pro Gly Ser Gly Ser Gln Asp Trp Ser Tyr Gly Leu Arg Pro Gly

2930
 GGA TCC TAG
 Gly Ser ---

FIG. 5H

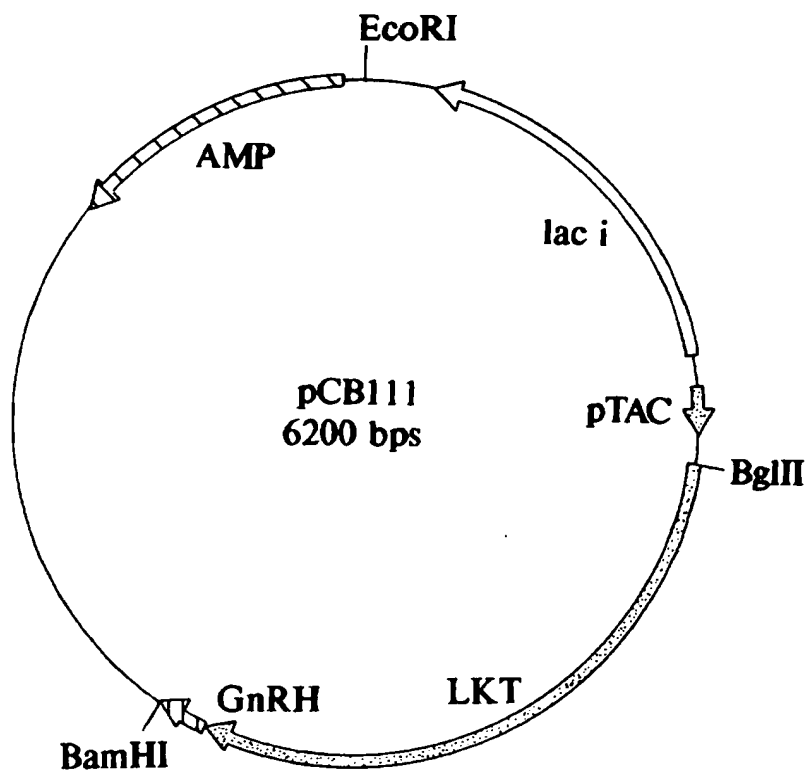


FIG. 6

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21 / 25

10 20 30 40
ATG GCT ACT GTT ATA GAT CTA AGC TTC CCA AAA ACT GGG GCA AAA
MET Ala Thr Val Ile Asp Leu Ser Phe Pro Lys Thr Gly Ala Lys

50 60 70 80 90
AAA ATT ATC CTC TAT ATT CCC CAA AAT TAC CAA TAT GAT ACT GAA
Lys Ile Ile Leu Tyr Ile Pro Gln Asn Tyr Gln Tyr Asp Thr Glu

100 110 120 130
CAA GGT AAT GGT TTA CAG GAT TTA GTC AAA GCG GCC GAA GAG TTG
Gln Gly Asn Gly Leu Gln Asp Leu Val Lys Ala Ala Glu Glu Leu

140 150 160 170 180
GGG ATT GAG GTA CAA AGA GAA GAA CGC AAT AAT ATT GCA ACA GCT
Gly Ile Glu Val Gln Arg Glu Glu Arg Asn Asn Ile Ala Thr Ala

190 200 210 220
CAA ACC AGT TTA GGC ACG ATT CAA ACC GCT ATT GGC TTA ACT GAG
Gln Thr Ser Leu Gly Thr Ile Gln Thr Ala Ile Gly Leu Thr Glu

230 240 250 260 270
CGT GGC ATT GTG TTA TCC GCT CCA CAA ATT GAT AAA TTG CTA CAG
Arg Gly Ile Val Leu Ser Ala Pro Gln Ile Asp Lys Leu Leu Gln

280 290 300 310
AAA ACT AAA GCA GGC CAA GCA TTA GGT TCT GCC GAA AGC ATT GTA
Lys Thr Lys Ala Gly Gln Ala Leu Gly Ser Ala Glu Ser Ile Val

320 330 340 350 360
CAA AAT GCA AAT AAA GCC AAA ACT GTA TTA TCT GGC ATT CAA TCT
Gln Asn Ala Asn Lys Ala Lys Thr Val Leu Ser Gly Ile Gln Ser

370 380 390 400
ATT TTA GGC TCA GTA TTG GCT GGA ATG GAT TTA GAT GAG GCC TTA
Ile Leu Gly Ser Val Leu Ala Gly MET Asp Leu Asp Glu Ala Leu

FIG. 7A
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22 / 25

410 420 430 440 450
CAG AAT AAC AGC AAC CAA CAT GCT CTT GCT AAA GCT GGC TTG GAG
Gln Asn Asn Ser Asn Gln His Ala Leu Ala Lys Ala Gly Leu Glu

460 470 480 490
CTA ACA AAT TCA TTA ATT GAA AAT ATT GCT AAT TCA GTA AAA ACA
Leu Thr Asn Ser Leu Ile Glu Asn Ile Ala Asn Ser Val Lys Thr

500 510 520 530 540
CTT GAC GAA TTT GGT GAG CAA ATT AGT CAA TTT GGT TCA AAA CTA
Leu Asp Glu Phe Gly Glu Gln Ile Ser Gln Phe Gly Ser Lys Leu

550 560 570 580
CAA AAT ATC AAA GGC TTA GGG ACT TTA GGA GAC AAA CTC AAA AAT
Gln Asn Ile Lys Gly Leu Gly Thr Leu Gly Asp Lys Leu Lys Asn

590 600 610 620 630
ATC GGT GGA CTT GAT AAA GCT GGC CTT GGT TTA GAT GTT ATC TCA
Ile Gly Gly Leu Asp Lys Ala Gly Leu Gly Leu Asp Val Ile Ser

640 650 660 670
GGG CTA TTA TCG GGC GCA ACA GCT GCA CTT GTA CTT GCA GAT AAA
Gly Leu Leu Ser Gly Ala Thr Ala Ala Leu Val Leu Ala Asp Lys

680 690 700 710 720
AAT GCT TCA ACA GCT AAA AAA GTG GGT GCG GGT TTT GAA TTG GCA
Asn Ala Ser Thr Ala Lys Lys Val Gly Ala Gly Phe Glu Leu Ala

730 740 750 760
AAC CAA CTT GTT GGT AAT ATT ACC AAA GCC GTT TCT TCT TAC ATT
Asn Gln Val Val Gly Asn Ile Thr Lys Ala Val Ser Ser Tyr Ile

FIG. 7B

SUBSTITUTE SHEET (RULE 26)

23/25

770 780 790 800 810
 TTA GCC CAA CGT GTT GCA GCA GGT TTA TCT TCA ACT GGG CCT GTG
 Leu Ala Gln Arg Val Ala Ala Gly Leu Ser Ser Thr Gly Pro Val

820 830 840 850
 GCT GCT TTA ATT GCT TCT ACT GTT TCT CTT GCG ATT AGC CCA TTA
 Ala Ala Leu Ile Ala Ser Thr Val Ser Leu Ala Ile Ser Pro Leu

860 870 880 890 900
 GCA TTT GCC GGT ATT GCC GAT AAA TTT AAT CAT GCA AAA AGT TTA
 Ala Phe Ala Gly Ile Ala Asp Lys Phe Asn His Ala Lys Ser Leu

910 920 930 940
 GAG AGT TAT GCC GAA CGC TTT AAA AAA TTA GGC TAT GAC GGA GAT
 Glu Ser Tyr Ala Glu Arg Phe Lys Lys Leu Gly Tyr Asp Gly Asp

950 960 970 980 990
 AAT TTA TTA GCA GAA TAT CAG CGG GGA ACA GGG ACT ATT GAT GCA
 Asn Leu Leu Ala Glu Tyr Gln Arg Gly Thr Gly Thr Ile Asp Ala

1000 1010 1020 1030
 TCG GTT ACT GCA ATT AAT ACC GCA TTG GCC GCT ATT GCT GGT GGT
 Ser Val Thr Ala Ile Asn Thr Ala Leu Ala Ala Ile Ala Gly Gly

1040 1050 1060 1070 1080
 GTG TCT GCT GCT GCA GCC AAC TTA AAA GAT TTA ACA TTT GAA AAA
 Val Ser Ala Ala Ala Ala Asn Leu Lys Asp Leu Thr Phe Glu Lys

1090 1100 1110 1120
 GTT AAA CAT AAT CTT GTC ATC ACG AAT AGC AAA AAA GAG AAA GTG
 Val Lys His Asn Leu Val Ile Thr Asn Ser Lys Lys Glu Lys Val

1130 1140 1150 1160 1170
 ACC ATT CAA AAC TGG TTC CGA GAG GCT GAT TTT GCT AAA GAA GTG
 Thr Ile Gln Asn Trp Phe Arg Glu Ala Asp Phe Ala Lys Glu Val

FIG. 7C

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24 / 25

1180	1190	1200	1210	
CCT	AAT	TAT	AAA	GCA
Pro	Asn	Tyr	Lys	Ala
ACT	AAA	GAT	GAG	AAA
Thr	Lys	Asp	Glu	Lys
ATC	GAA	GAA	ATC	ATC
Ile	Glu	Glu	Ile	Ile
1220	1230	1240	1250	1260
GGT	CAA	AAT	GGC	GAG
Gly	Gln	Asn	Gly	Glu
CGG	ATC	ACC	TCA	AAG
Arg	Ile	Thr	Ser	Lys
CAA	GTT	GAT	GAT	CTT
Gln	Val	Asp	Asp	Leu
1270	1280	1290	1300	
ATC	GCA	AAA	GGT	AAC
Ile	Ala	Lys	Gly	Asn
GGC	AAA	ATT	ACC	CAA
Gly	Lys	Ile	Thr	Gln
GAT	GAG	CTA	TCA	AAA
Asp	Glu	Leu	Ser	Lys
1310	1320	1330	1340	1350
GTT	GTT	GAT	AAC	TAT
Val	Val	Asp	Asn	Tyr
GAA	TTG	CTC	AAA	CAT
Glu	Leu	Leu	Lys	His
AGC	AAA	AAT	GTG	ACA
Ser	Lys	Asn	Val	Thr
1360	1370	1380	1390	
AAC	AGC	TTA	GAT	AAG
Asn	Ser	Leu	Asp	Lys
TTA	ATC	TCA	TCT	GTA
Leu	Ile	Ser	Ser	Val
AGT	GCA	TTT	ACC	TCG
Ser	Ala	Phe	Thr	Ser
1400	1410	1420	1430	1440
TCT	AAT	GAT	TCG	AGA
Ser	Asn	Asp	Ser	Arg
AAT	GTA	TTA	GTG	GCT
Asn	Val	Leu	Val	Ala
CCA	ACT	TCA	ATG	TTG
Pro	Thr	Ser	<u>MET</u>	Leu
1450	1460	1470	1480	
GAT	CAA	AGT	TTA	TCT
Asp	Gln	Ser	Leu	Ser
TCT	TCT	CTT	CAA	TTT
Ser	Ser	Leu	Gln	Phe
GCT	AGG	GGA	TCT	CAG
Ala	Arg	Gly	Ser	Gln
1490	1500	1510	1520	1530
TGG	AGC	TAC	GGC	CTG
Trp	Ser	Tyr	Gly	Leu
CGC	CCT	GGC	AGC	GGT
Arg	Pro	Gly	Ser	Gly
TCT	CAA	GAT	TGG	AGC
Ser	Gln	Asp	Trp	Ser

FIG. 7D

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25/25

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      1540      1550      1560      1570
      |       |       |       |
TAC GGC CTG CGT CCG GGT GGC TCT AGC CAG CAT TGG AGC TAC GGC
Tyr Gly Leu Arg Pro Gly Gly Ser Ser Gln His Trp Ser Tyr Gly

      1580      1590      1600      1610      1620
      |       |       |       |       |
CTG CGC CCT GGC AGC GGT AGC CAA GAT TGG AGC TAC GGC CTG CGT
Leu Arg Pro Gly Ser Gly Ser Gln Asp Trp Ser Tyr Gly Leu Arg

      1630
      |
CCG GGT GGA TCC TAG
Pro Gly Gly Ser ---

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FIG. 7E

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      [NaeI]                                [BstBI]
..GCT GCA GCC|GGC TCG GTT ATT...TTC TCT GAT TCG|AAC TTA AAA..
..CGA CGT CGG|CCG AGC CAA TAA...AAG AGA CTA AGC|TTG AAT TTT..
..Ala Ala Ala|Gly Ser Val Ile...Phe Ser Asp Ser|Asn Leu Lys..
      351                                785

```

FIG. 8A

```

..GCT GCA GCC AAC TTA AAA..
..CGA CGT CGG TTG AAT TTT..
..Ala Ala Ala Asn Leu Lys..
      351 785

```

FIG. 8B

SUBSTITUTE SHEET (RULE 26)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 96/00049

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C12N15/62 C07K19/00 C07K7/23 A61K38/09 A61K39/385

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C12N C07K A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO,A,93 08290 (UNIV SASKATCHEWAN) 29 April 1993 cited in the application see page 4, line 11 - line 12 see page 8, line 2 - line 3 ---	1-14
Y	VACCINE, vol. 12, no. 8, June 1994, GUILDFORD GB, pages 741-746, XP000570334 MELOEN R.H. ET AL.: "Efficient immunocastration of male piglets by immunoneutralization of GnRH-like peptide" cited in the application see page 741, column 2 see page 742, column 1 see page 743, column 2 see Discussion --- -/--	1-14

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

17 May 1996

Date of mailing of the international search report

0 7. 06. 96

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INTERNATIONAL SEARCH REPORT

Int. Patent Application No
PCT/CA 96/00049

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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